CURED FISH PRODUCTION IN THE TROPICS

edited by

A. Reilly and L. E. Barile

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CURED FISH PRODUCTION IN THE TROPICS

Proceedings of a Workshop held at the Department of Fish Processing Technology, College of Fisheries, University of the Philippines in the Visayas, Diliman Quezon City, Philippines

14 - 25 April 1986

edited by:

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ABSTRACT

This publication contains sixteen papers presented and discussed at a Workshop on Cured Fish Production in the Tropics held as part of the extension programme of the Philippine German Fisheries Project at the Department of Fish Processing Technology, College of Fisheries, University of the Philippines in the Visayas, 14-25 April 1986. These papers cover the following topics: Principles of Fish Drying and Salting; Utilization and Design of Agrowaste Fish Dryers; Mycotoxins in Cured Fish; Fish Smoking; Production and Marketing of Cured Fish.

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PRINCIPLES OF FISH DRYING AND SPOILAGE

by

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Australia

1. Introduction

This paper is a set of lecture notes covering in detail various aspects of drying and spoilage of dried fish. The order follows that of the lectures given at the workshop: Fundamentals of drying including a discussion on the importance of water activity; sorption isotherms; the physics of drying; microbial spoilage. The paper also includes some material that was prepared for individuals and not presented in the lectures; for example the method of calculating water activity from salt, fat and moisture contents, principles of psychrometry and suggestions for the use of Lufft water activity meters.

2. Fundamentals of drying

2.1 Water activity

Drying and curing of fish as methods of preservation are centuries-old practices. We can look at other methods of preservation, for example freezing, fermentation or hot smoking and ask what natural processes occur in these methods which have the result of slowing down the spoilage. So far as microbial spoilage is concerned, and to a lesser extent spoilage due to insects, autolysis, etc., the most important factor for dried products is water activity.

Water activity is a measure of the 'free' or loosely bound water within a foodstuff. Scott (1936) working in the laboratories of the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia is generally credited with the water activity concept. His successors at the same laboratory, Troller and Christian (1978), have extended the work to cover the relationship between water activity and the other food spoilage factors like moulds, enzymes, oxidation, etc.

Do not conclude that water activity is the only factor in fish spoilage. Anything that can make life difficult for the spoilage organisms such as a change in temperature, or pH, or the amount of air present, will slow down growth rates and result in an increase of shelf-life. The principle is to place a stress, or a combination of stress factors, on the microorganisms or insects likely to cause the spoilage. The same principle applies to autolysis

and browning reactions although in these cases the effects of temperature and water activity changes are less clearly understood.

2.1.1 Measurement of water activity

Water activity is measured by placing a sample of the material in a closed container. The relative humidity of the air within the container is measured using some form of hygrometer and the value of the relative humidity obtained is used as the measure of water activity, expressed as a function in the range 0 to 1. Water activity is usually abbreviated as a_w or A_w. A number of different types of measuring instruments are available; for more details see Troller (1983).

The Lufft A_w meters, which use a hair hygrometer to measure the relative humidity, are relatively cheap and robust and will give reliable measurements if used properly. It is important to realise that instruments are temperature sensitive and should be used in a room or an incubator which has a controlled temperature to within about $\pm$ 2^{o}C. It is also important that enough time is allowed for the air above the sample to reach equilibrium. This takes a minimum of 4 h if the instruments are used at 20^{o}C and 2 h at 30^{o}C.

The Lufft instruments exhibit hysterics and drift off calibration. It is therefore essential to regularly calibrate the sensor heads against a standard saturated salt solution (use NaCl or $BaCl_2$ poured onto filter paper - there must be undissolved crystals of the salt present to ensure that the solution remains saturated). The manufacturer recommends a system of 'swapping sensors' which gives a continuous calibration. This tends to be confusing for large numbers of samples and sensors unless a good system of recording the results is used. For routine analysis, a two point calibration (A_w 0.75 and A_w 0.9) every 2 days for each sensor should ensure accurate results. There is no need to macerate the fish sample, use only about 3 to 5 g of flesh and stick to the 2 h at 30^{o}C.

Using the Lufft A_w meter as described above with regular calibration and adequate temperature control and equilibration time will give a reliable measurement of A_w to within $\pm$ 0.01. That is, a reading of 0.86 is probably within the range of 0.85 to 0.87.

2.1.2 Calculation of A_w from measured salt, moisture and fat contents

Because of the cost of the A_w meters and their difficulty of use in tropical conditions, the method of calculating water activity from measurements of salt, moisture and fat contents may be preferred.

This method has the advantage in that if the salt and fat contents of the fresh or brined fish are known or measured, then the water activity can be

calculated from the moisture content alone, and thus can be monitored as the fish dries.

The method is described in Doe, Curran and Poulter (1983) and is repeated in Table 1 in greater detail with an example calculation for a sample of dried salted fish.

Table 1 Calculation of water activity from moisture, salt and fat contents

---

Moisture content: Mass of sample = 12.63g ($=M_1$)
Mass after oven drying at 105°C for 24 h = 7.07g ($=M_{24}$)

$$\text{Calculated } \frac{M_{24}}{M_1} = \frac{7.07}{12.63} = 0.56$$

$$\text{Calculated moisture content } \frac{M_1 - M_{24}}{M_1} = \frac{12.63 - 7.07}{12.63} = 0.44$$

Salt content: Mass of sample = 13.72g ($=M_2$)
(Measure salt content by standard method)

Mass of salt in sample = 1.36g ($=M_s$)

$$\text{Calculated } \frac{M_s}{M_2} = \frac{1.36}{13.72} = \underline{0.099}$$

Fat content: Mass of sample = 14.32g ($=M_3$)
(Measure fat content by standard method)

Mass of fat in sample = 0.23g ($=M_f$)

$$\text{Calculate } \frac{M_f}{M_3} = \frac{0.23}{14.32} = \underline{0.016}$$

Then calculate the fat-free, salt-free, bone dry mass (M_b) as follows:

$$\frac{M_b}{M} = \frac{M_{24}}{M_1} - \frac{M_s}{M_2} - \frac{M_f}{M_3} = \underline{0.56 - 0.099 - 0.016}$$

$$= \underline{0.445}$$

this gives the salt content f.f.d.b. $\frac{M_s}{M_b} = \frac{0.099}{0.445} = \underline{0.22}$

also the moisture content, fat-free, salt-free dry basis

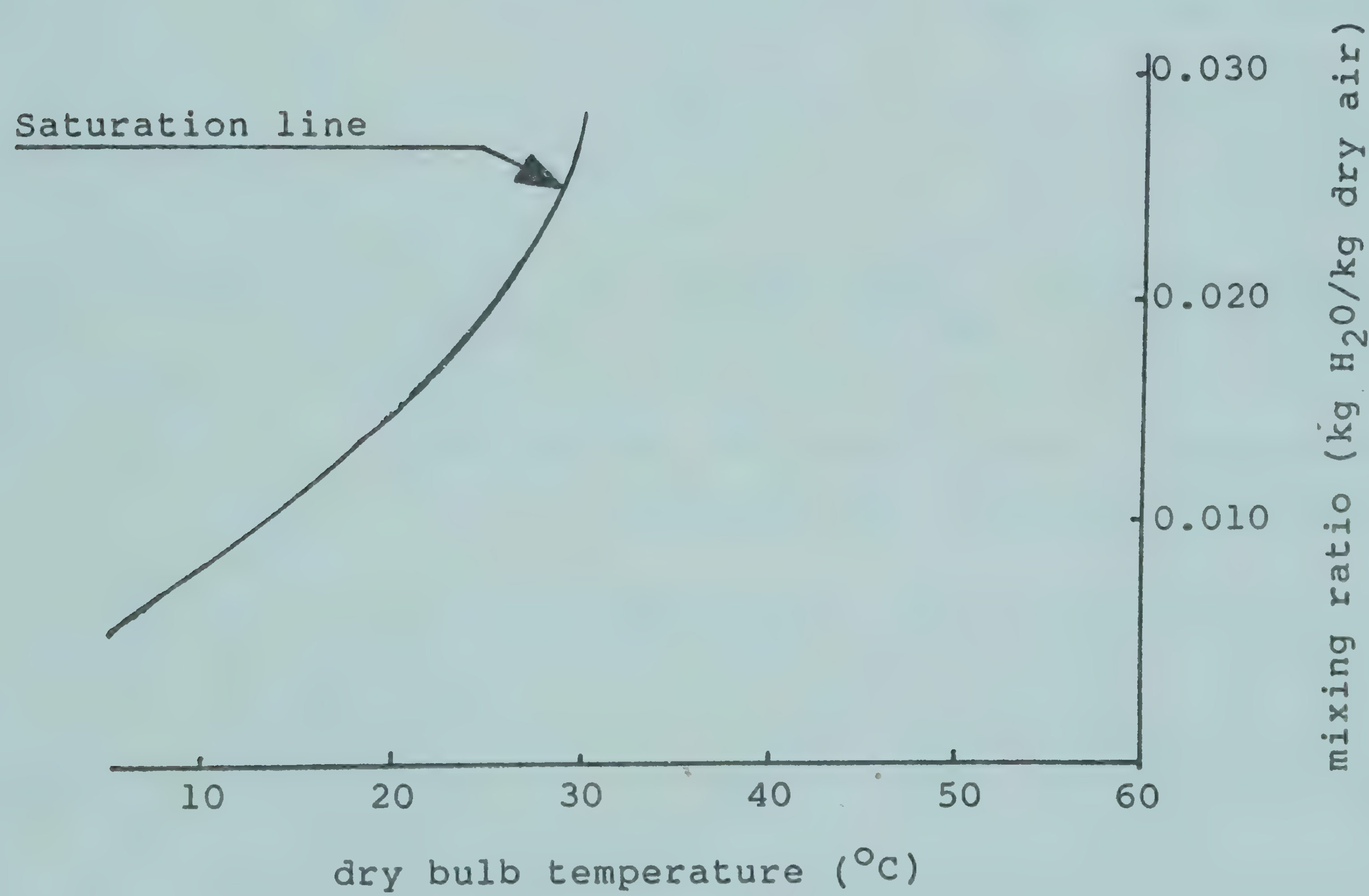
$$\frac{M_w}{M_b} = \frac{0.440}{0.445} = \underline{0.99}$$

Then from Table 2 [Doe, Curran and Poulter, (1983)] read off the value of A_w corresponding to the calculated salt and moisture contents. In this case $A_w = 0.86$.

2.1.3 Psychrometry

Psychrometry is the study of moisture in air. Air has a limited capacity to absorb water vapour. When this capacity is reached the air is said to be saturated. The moisture content at saturation varies with temperature as shown in Figure 1.

Figure 1 Psychrometric chart



Moist air can be thought of as a mixture of two gases - dry air with a molecular weight of 29.1 and water vapour with a molecular weight of 18. We

Table 2 Water activities from water and salt contents

Salt content (M_s/M_b)

Water content (M_w/M_b)	0	.02	.04	.06	.08	.10	.12	.14	.16	.18	.20	.22	.24	.26	.28
.02	.04	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
.04	.09	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07
.06	.17	.13	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12
.08	.26	.21	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19
.10	.47	.41	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35
.12	.59	.53	.46	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44
.14	.69	.63	.56	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51
.16	.75	.69	.63	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56
.18	.80	.74	.68	.61	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60
.20	.83	.79	.73	.67	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
.22	.86	.82	.77	.71	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65
.24	.89	.85	.80	.75	.69	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67
.26	.91	.87	.82	.78	.72	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68
.28	.93	.89	.85	.80	.75	.70	.69	.69	.69	.69	.69	.69	.69	.69	.69
.32	.95	.92	.88	.84	.80	.75	.71	.71	.71	.71	.71	.71	.71	.71	.71
.36	.96	.93	.90	.87	.83	.79	.74	.72	.72	.72	.72	.72	.72	.72	.72
.40	.97	.95	.92	.89	.85	.82	.78	.74	.73	.73	.73	.73	.73	.73	.73
.44	.98	.96	.93	.90	.87	.84	.81	.77	.74	.74	.74	.74	.74	.74	.74
.48	.99	.96	.94	.91	.89	.86	.83	.80	.76	.74	.74	.74	.74	.74	.74
.52	.99	.97	.95	.93	.90	.87	.85	.82	.79	.75	.74	.74	.74	.74	.74
.56	1.0	.98	.96	.93	.91	.89	.86	.84	.81	.78	.75	.75	.75	.75	.75
.60	1.0	.98	.96	.94	.92	.90	.87	.85	.82	.80	.77	.75	.75	.75	.75
.64	1.0	.98	.96	.94	.93	.90	.88	.86	.84	.81	.79	.76	.75	.75	.75
.68	1.0	.98	.97	.95	.93	.91	.89	.87	.85	.83	.80	.78	.75	.75	.75
.72	1.0	.98	.97	.95	.93	.92	.90	.88	.86	.84	.82	.78	.77	.75	.75
.76	1.0	.99	.97	.96	.94	.92	.90	.89	.87	.85	.83	.81	.79	.76	.75
.80	1.0	.99	.97	.96	.94	.93	.91	.89	.88	.86	.84	.82	.80	.78	.76
.84	1.0	.99	.97	.96	.95	.93	.92	.90	.88	.87	.85	.83	.81	.79	.77
.88	1.0	.99	.98	.96	.95	.93	.92	.90	.89	.87	.86	.84	.82	.80	.79
.92	1.0	.99	.98	.96	.95	.94	.92	.91	.89	.88	.86	.85	.83	.81	.80
.96	1.0	.99	.98	.97	.95	.94	.93	.91	.90	.88	.87	.85	.84	.82	.81
1.0	1.0	.99	.98	.97	.96	.94	.93	.92	.90	.89	.88	.86	.85	.83	.82
1.5	1.0	.99	.98	.98	.97	.96	.95	.95	.94	.93	.92	.91	.90	.89	.89
2.0	1.0	1.0	.99	.98	.98	.97	.97	.96	.96	.95	.94	.94	.93	.92	.92
2.5	1.0	1.0	.99	.99	.98	.98	.97	.97	.96	.96	.96	.95	.95	.94	.94
3.0	1.0	1.0	.99	.99	.99	.98	.98	.97	.97	.97	.96	.96	.96	.95	.95
3.5	1.0	1.0	.99	.99	.99	.98	.98	.98	.98	.97	.97	.96	.96	.96	.96
4.0	1.0	1.0	1.0	.99	.99	.99	.98	.98	.98	.98	.97	.97	.97	.96	.96

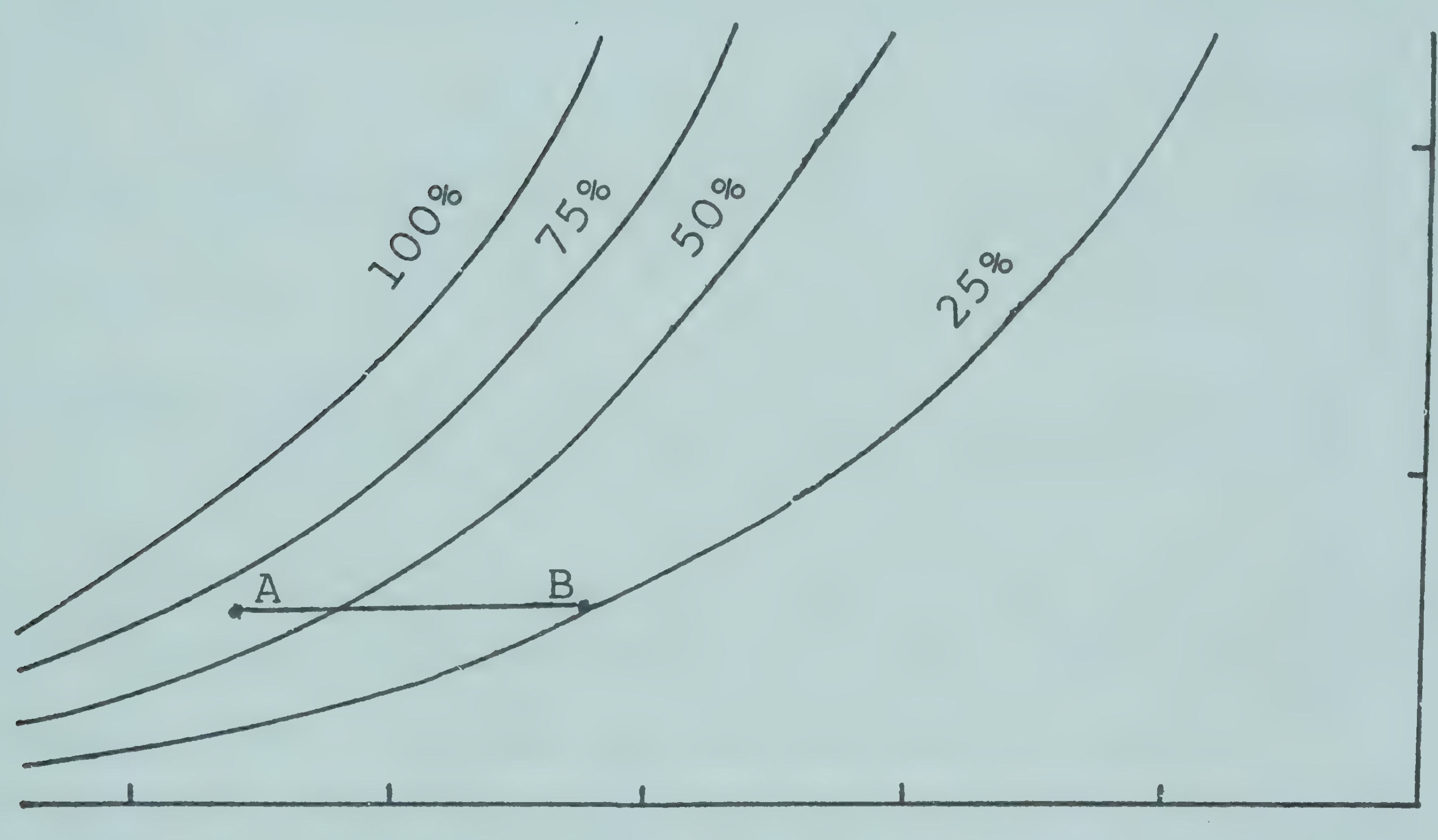
Water content (M_w/M_b)	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0
.02	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
.04	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07
.06	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12
.08	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19
.10	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35
.12	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44
.14	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51
.16	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56
.18	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60
.20	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
.22	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65
.24	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67
.26	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68
.28	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69
.32	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
.36	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72
.40	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73
.44	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74
.48	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74
.52	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74
.56	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.60	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.64	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.68	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.72	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.76	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.80	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.84	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.88	.76	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.92	.78	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.96	.79	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
1.0	.80	.76	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
1.5	.88	.85	.83	.80	.77	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
2.0	.91	.89	.88	.86	.84	.82	.80	.78	.76	.75	.75	.75	.75	.75	.75
2.5	.93	.92	.90	.89	.88	.87	.85	.83	.82	.80	.78	.77	.75	.75	.75
3.0	.94	.93	.92	.91	.90	.89	.88	.86	.85	.84	.83	.81	.80	.79	.77
3.5	.95	.94	.93	.92	.92	.91	.90	.89	.88	.87	.86	.84	.83	.82	.81
4.0	.96	.95	.94	.93	.93	.92	.91	.90	.89	.88	.88	.87	.86	.85	.84

express the proportion of this mixture in many ways. On the psychrometric chart the ratio of water vapour to dry air (M_w/M_a) is used. This is called 'mixing ratio', 'specifics humidity' or 'moisture content'. There are other ways of expressing the ratio, for example mole fraction, absolute humidity, vapour pressure and relative humidity. Of these only relative humidity is worth considering here as it is easily measured (using a psychrometer) and has direct relevance to drying and water activity.

Relative humidity is strictly defined in terms of vapour pressure, but can be expressed as the ratio of the 'mixing ratio' of air to the 'mixing ratio' of air which is saturated at the same temperature.

Lines of constant relative humidity appear as curves on the psychrometric chart as shown in Figure 2.

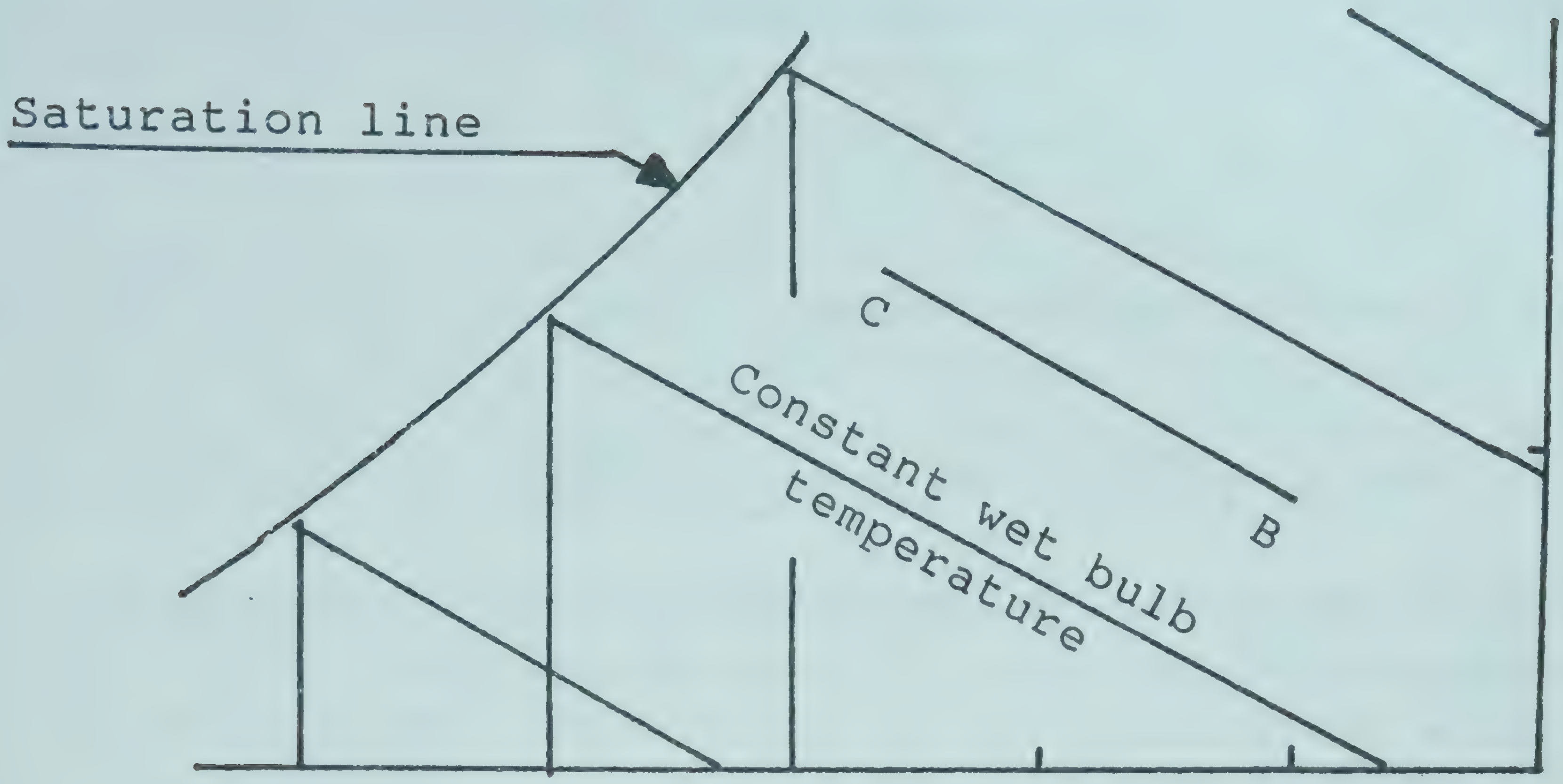
Figure 2 Psychrometric chart, %rh



Note that if air is heated at constant moisture content, as is the case in a solar or agrowaste dryer, then the air state moves along a horizontal line on the psychrometric chart from A to B in Figure 2. This has the effect of reducing the relative humidity of the air.

Relative humidity is usually measured with a psychrometer which gives the 'dry bulb' air temperature and a 'wet bulb' temperature from a thermometer which has a wet wick. Lines of constant wet bulb temperature are at a slope as shown in Figure 3.

Figure 3 Psychrometric chart - wet bulb lines



Note that the wet bulb lines meet the dry bulb lines on the saturation line - here dry bulb equals wet bulb and the air is fully saturated and thus useless for drying. Lines of constant wet bulb temperature are close to adiabatic or 'constant heat' lines. What this means in practice is that air passing over fish in a dryer will gain moisture and decrease in temperature along a line of constant wet bulb temperature. That is from B to C in Figure 3. This can be used to monitor drying rates. If the air leaving the top of a dryer is saturated then the dryer is operated at its maximum capacity. Knowing the air flow rate and the temperature and humidity of the inlet and exhaust air, the drying rate can then be calculated.

Of course a detailed knowledge of psychrometry is not necessary to be able to dry fish - but an understanding of how air and water relate and the processes occurring in a dryer will improve effectiveness and efficiency of dryer operation.

2.2 Moisture content

Moisture content of fish is usually measured by drying for 24 h at 105°C. As indicated in Table 1, there are various ways of specifying moisture content depending on whether salt and fat are to be included in the residual mass found after oven drying. The most common expression for moisture content is moisture content wet basis which is

$$mcwb = \frac{M - M_{24}}{M}$$

where M is mass of sample before drying and M_{24} is mass after drying 24 h at 105°C and cooling in a dessicator before weighing.

Alternatively the dry basis moisture content can be given:

$$\text{mcdb} = \frac{M - M_{24}}{M_{24}}$$

These two are related by the formulae

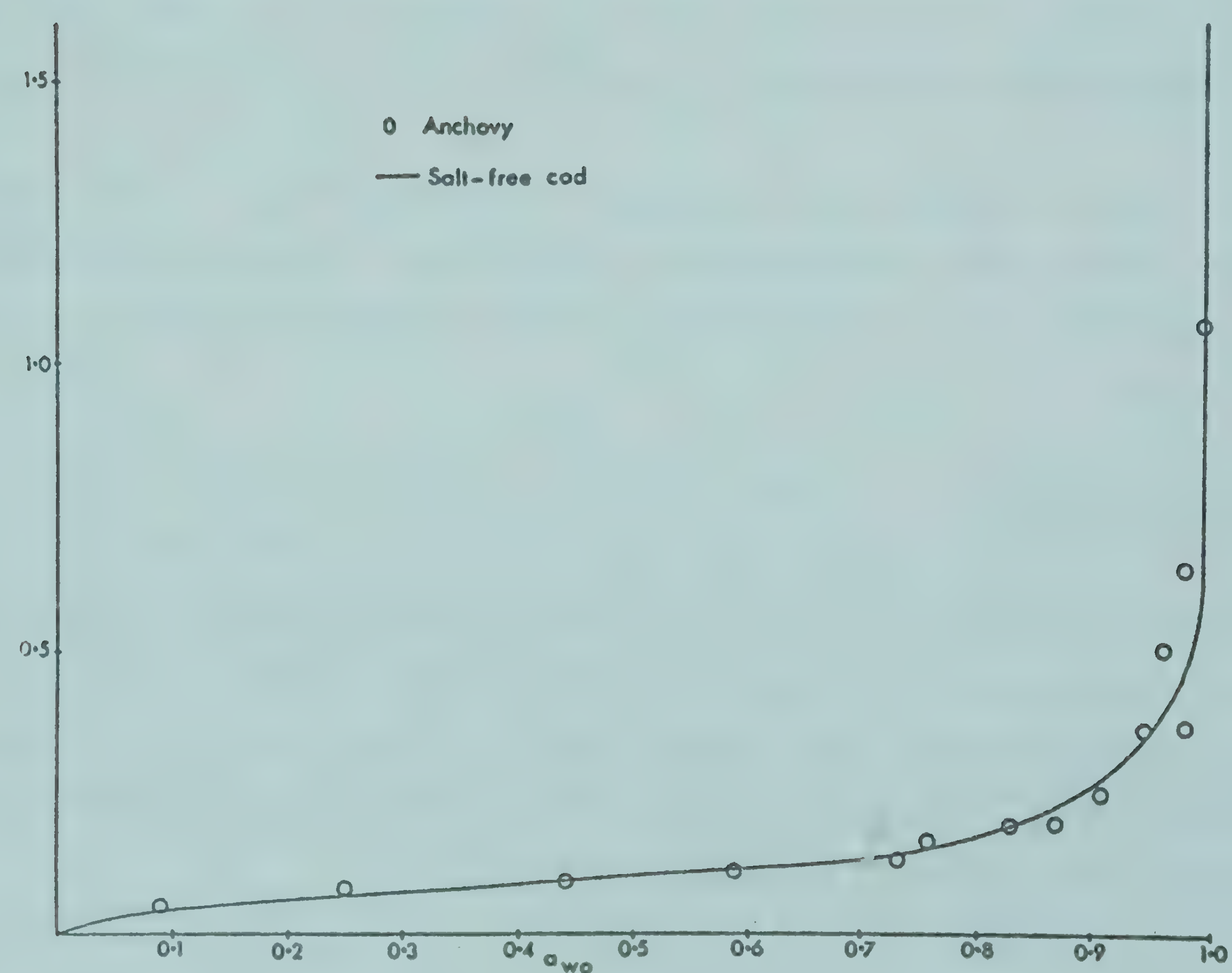
$$\text{mcwb} = \frac{\text{mcdb}}{1 + \text{mcdb}} \quad \text{and} \quad \text{mcdb} = \frac{\text{mcwb}}{1 - \text{mcwb}}$$

Calculation of moisture content on fat-free, salt-free basis is shown in Table 1.

2.3. Sorption isotherms

Sorption isotherms or 'equilibrium moisture content diagrams' are a way of showing the relationship between moisture content and water activity. For foodstuffs such as fish, the sorption isotherms are a series of S-shaped curves as shown in Figure 4.

Figure 4 Typical sorption isotherm for low salt fish



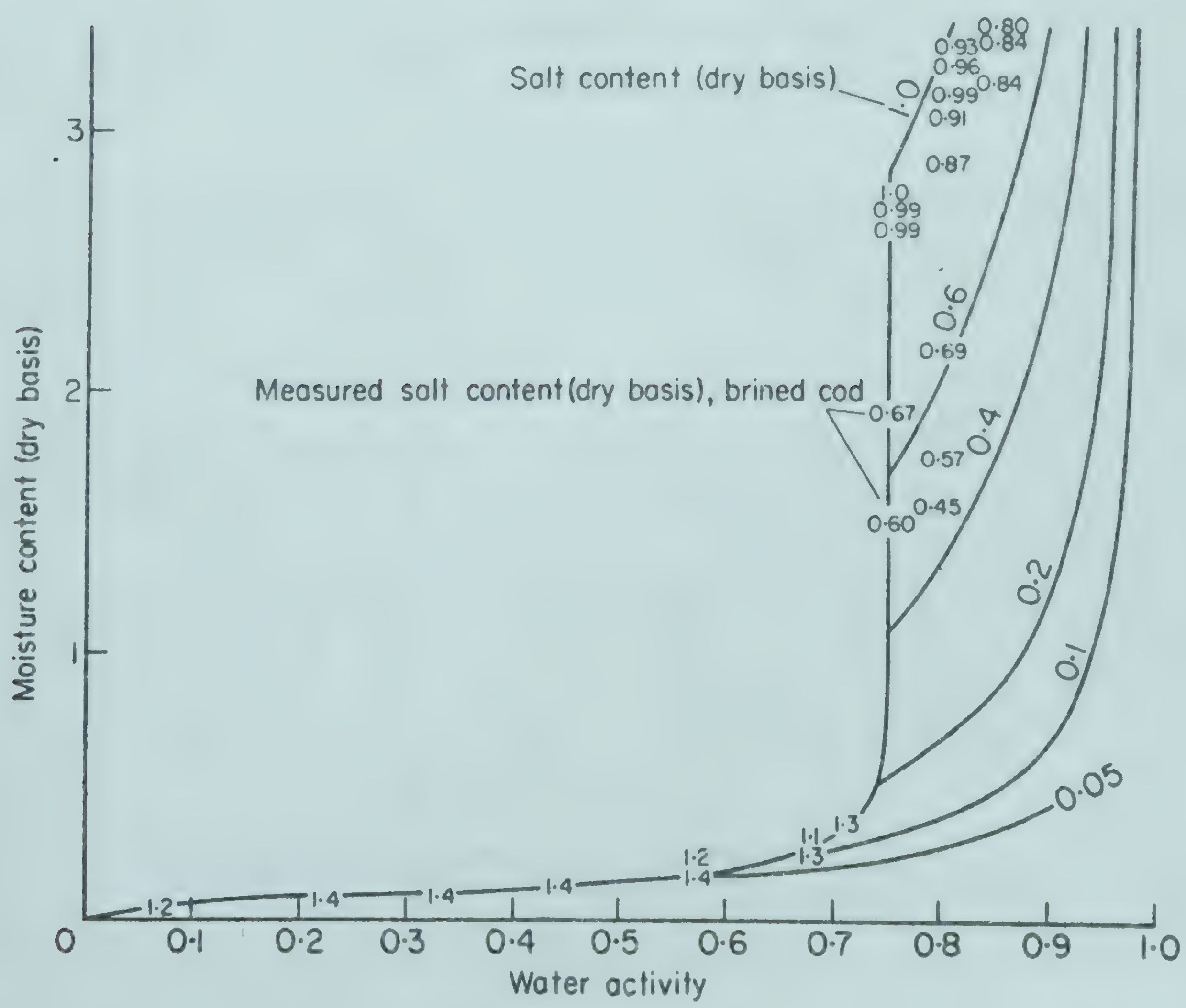
There are two methods of measuring the sorption behaviour so that sorption isotherms can be plotted. The first method is to allow samples of the fish to equilibrate to different relative humidities in the air space in closed containers above different saturated salt solutions at different temperatures. The second method is to dry samples to different moisture contents and then measure the water activity of the samples in an A_W meter.

Both methods are time consuming and difficult, particularly at high A_W values when samples can spoil before equilibration. Fortunately, those are mathematical expressions which give a good fit to most foodstuffs. Thus only a small number of readings need to be taken to give a complete set of sorption isotherms (Chiriffe and Iglesias, 1978).

There is a complication in that the measured sorption isotherms differ depending on whether they were measured by a desorption or absorption process. Such deviations are small for dried fish and are usually ignored except in cases where very accurate knowledge of sorption behaviour is required.

Knowledge of the sorption behaviour of fish is of great benefit in determining the amount of drying needed to produce a dried product with a given shelf-life. As moisture is removed during drying, the water activity decreases as the drying process moves down along an isotherm. The fish are properly dry when the required A_W is reached. This value will depend on the desired keeping quality of the fish.

Figure 5 Isohalic sorption isotherms



The moisture content at which the desired A_w value is reached will depend on salt and fat contents. Figure 5 illustrates the effect of salt on the sorption isotherms. The 'isohalic' or constant salt isotherms are described in detail by Doe, Poulter and Olley (1982).

As can be seen in Figure 5 the addition of salt to fish bring the water activity down to 0.75 at much higher moisture contents than in the case for unbrined fish. The greater the salt content of the fish, the lesser the amount of water that needs to be removed during drying to achieve the same value of water activity.

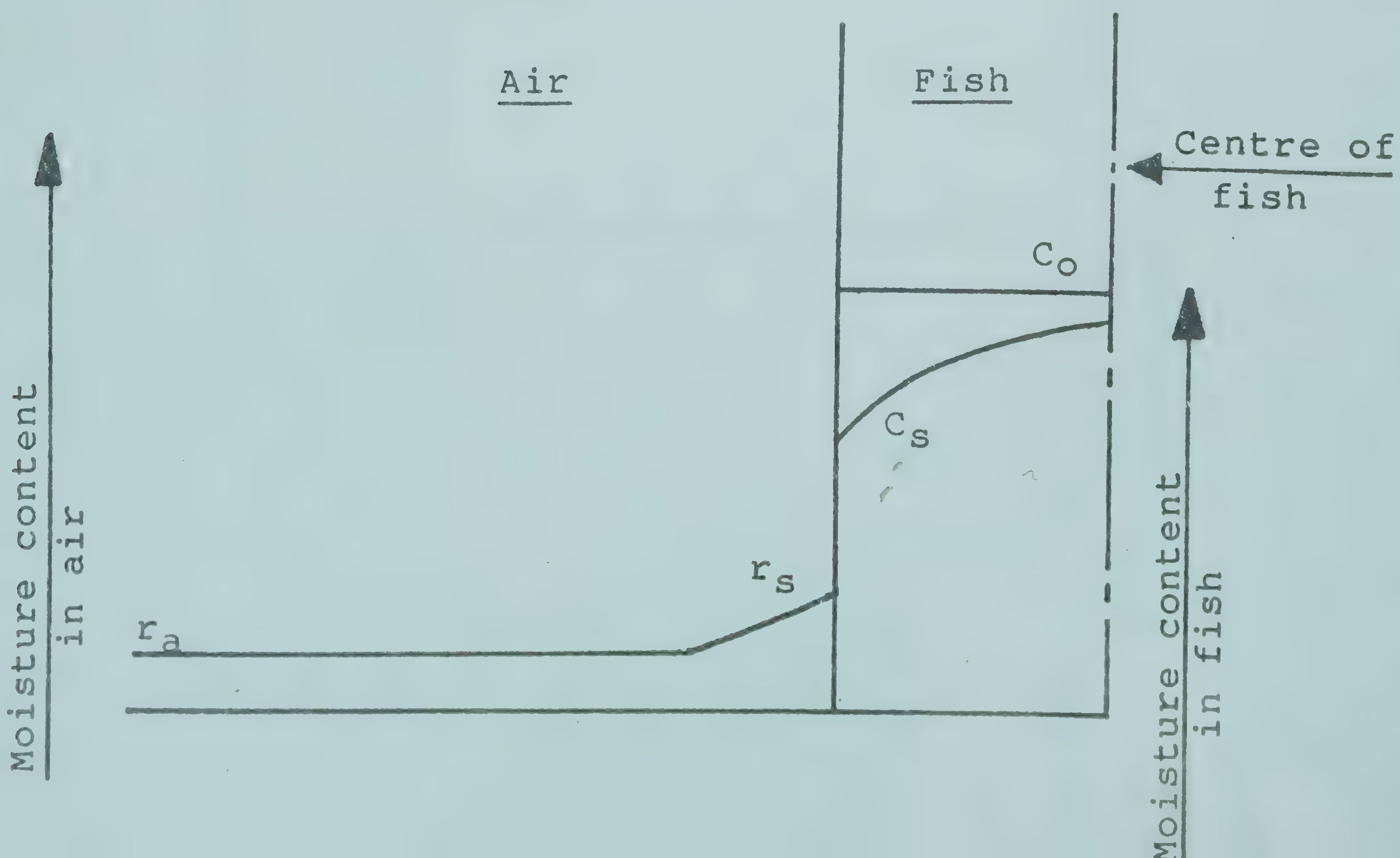
2.4 Diffusion and convection

The process of drying involves the movement of water through a solid and its evaporation from a surface. These processes are known as diffusion and convection respectively. In a porous open solid, like a sponge, there is very little resistance to water diffusion, hence evaporation is the governing process. Such solids dry at 'constant rate'. Alternatively, a solid in which the water is tightly bound, or in which there are barriers which prevent free movement of water to a surface, will dry under diffusion governing conditions. Such drying is termed 'falling rate' as the rate of drying decreases as water diffuses out of the solid.

Fish drying is usually characterised by a period of constant rate drying followed by a longer period of falling rate drying.

The factors governing the rate of drying are illustrated in Figure 6.

Figure 6 Moisture concentration in drying



Initially the moisture content is close to uniform throughout the fish (C_0). As water leaves the surface its moisture content drops to some value C_s, which is close to being in equilibrium with the surrounding air. The humidity of the air close to the surface r_s is directly related to the moisture content C_s at the surface by the sorption isotherm.

Outside the fish, the evaporation rate e, can be found from the expression

$$e = h_m A (r_s - r_a),$$

where h_m is the surface mass transfer coefficient (m/s),

e is the evaporation rate (kg/s),
A is the surface area (m^2)
and r_s and r_a are humidities at the surface and of ambient air respectively (kg H_2O/m^3).

The surface mass transfer coefficient depends on wind speed and aerodynamic shape. Thus rate of evaporation from the surface can be increased by:

- increasing airspeed,
- increasing surface area,
- decreasing the humidity of the air within the dryer, thus increasing ($r_s - r_a$).

Within the fish, diffusion rate of water to the surface is given by

$$e = \frac{2.D.A}{b} (C_o - C_s)$$

where e is the rate of movement of water from within the fish to the surface (kg/s)

D is the diffusion coefficient or mass diffusivity (m^2/s)
C_o and C_s are moisture concentrations (kg H_2O/m^3)
and b is the thickness of the fish (m)

Thus the rate of diffusion can be increased by:

- increasing mass diffusivity,
- increasing surface area,
- decreasing the thickness of the fish and to a lesser extent, decreasing the moisture content at the surface

Apart from cutting the fish into thinner pieces, the only practical way to increase the rate of diffusion governing drying is to increase the drying temperature and hence the diffusivity. This obviously has limitations due to the fish cooking at temperature above 40°C, depending on moisture content.

The two processes of diffusion and convection are not independent. However, while r_s remains constant, the drying takes place at constant rate whereas when r_s starts to fall due to the fish drying out, the rate starts to decrease.

This fact explains the different drying behaviour of brined and unbrined fish. In unbrined fish the sorption isotherm remains close to A_w = 1.0 while the moisture content drops (see Figure 4). However, the presence of salt changes the sorption isotherm so that A_w and hence r_s begins to drop at quite high moisture contents. Thus salted fish exhibit a very short constant rate drying period and are generally slower to dry than unsalted fish.

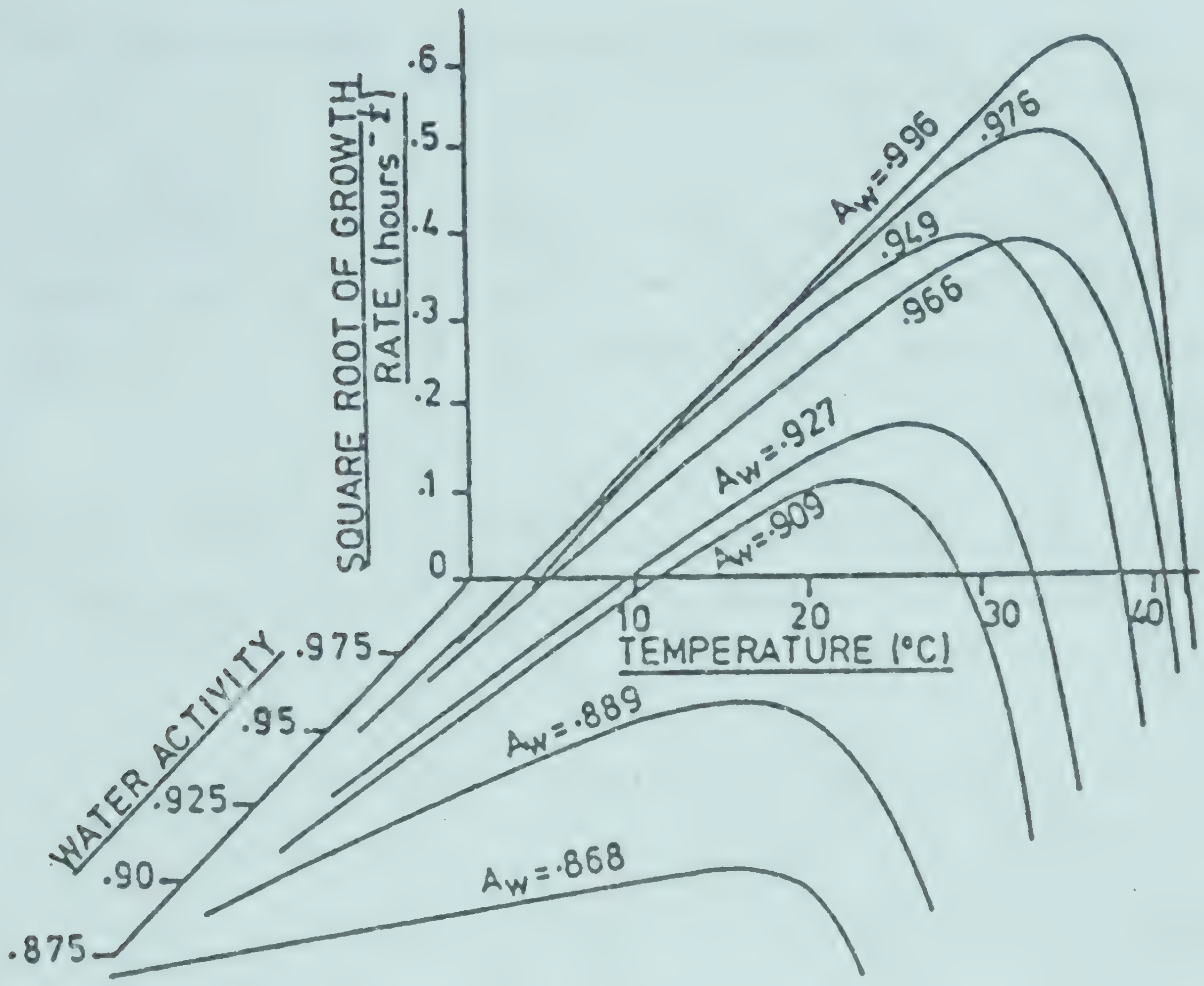
3. Bacterial spoilage

The water activity of a dried fish product can be used to predict the shelf-life of the fish. A storage trial of different tropical fish carried out by Poulter *et al*. (1982) gave a good agreement between measured shelf-life under the usual ambient temperature and humidity storage conditions in Sri Lanka and a shelf-life predicted from the known water activity tolerance of one of the spoilage moulds *Wallemia sebi*.

This work has been extended by a team in Australia and Indonesia which is making careful measurements of the rates of growth of several bacteria and moulds found to be spoilers of tropical fish in Indonesia (Doe, 1985).

An interesting discovery is that the growth rate of these organisms varies with temperature at lowered water activity in much the same way as for bacteria which grow best at A_w = 1.0. The minimum temperature to sustain growth does not appear to change with decreased water activity as shown in Figure 7.

Figure 7 Growth rate temperature - water activity curves for a halotolerant strain of Micrococcus



One of the aims of the ACIAR (Australian Centre for International Agricultural Research) sponsored project is to combine all the growth rate data for the various bacteria and moulds likely to cause spoilage into a 'model' of the spoilage process which can be used to calculate safe drying times and temperatures and also expected shelf-life under known storage conditions.

4. Conclusion

Knowing the details of drying processes, water activity, sorption isotherms and the like will not make the fish dry any faster. Nor will this information be of any assistance to the people in fishing villages, who dry fish. However, scientists, technologists and researchers, who are trying to improve drying technology and hygiene, will find that an understanding of the physical and biological processes involved in fish drying will give them confidence that the new techniques they may provide for fish processing will work, will be cost effective and hopefully will lead to a reduction in waste and an improved standard of living for all those involved.

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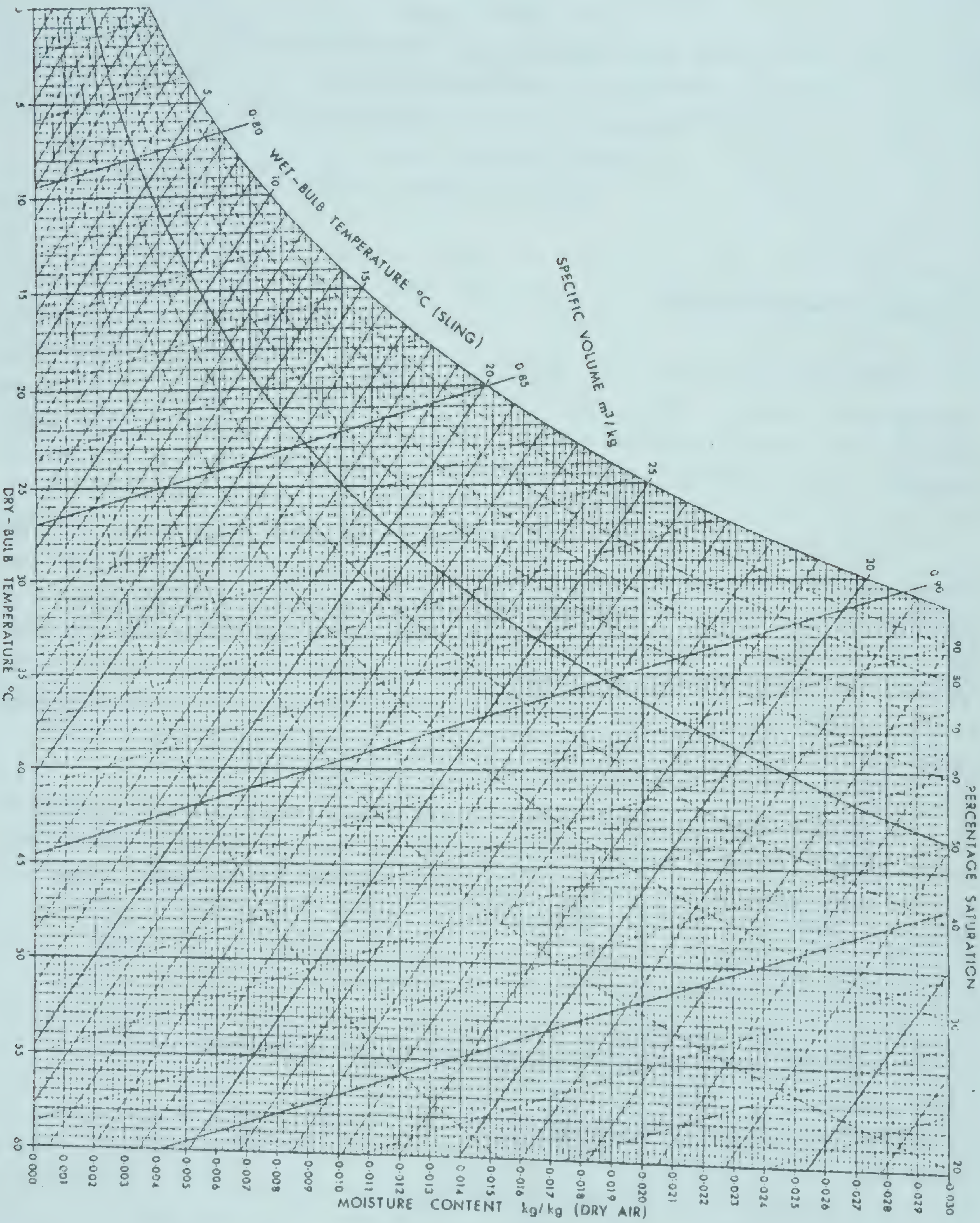

WATER ACTIVITY IN PRESERVED FISH PRODUCTS*

by

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1. What is water activity

For centuries man has been consuming foods with relatively long keeping-time periods. Among these we can mention cheese, cereal, flour (and bread), sugar, nuts and coffee grains, dried figs, honey, salted meat and vegetables (olives) and also salted or salted and dried fish.

Man discovered a long time ago that the common denominator for the exceptionally long keeping-time of these products was a low water content when compared to that found in fresh raw food and/or the presence of additives such as salt or sugar. Nevertheless, attempts to relate the water content of a product (or the salt or sugar content) with the keeping time in general failed since different products with the same water (or salt or sugar) content reacted differently.

It was only recently (Scott, 1953; 1957) that the other parameter-water activity - was credited for the analysis of the stability of these foods rather than water content alone or combination of the salt or sugar content.

The total moisture content in a food can include the following:

(i) water adsorptively bound to food constituents in a mono-molecular layer (e.g. over protein molecules);

(ii) chemically bound water;

(iii) water bound to hydrophilic colloids;

(iv) free unbound water.

The only water that is readily available to microorganisms is the free unbound water. Water activity is, in principle, a measure of this free water, i.e. as a true solvent and therefore susceptible to microorganism growth and enzymatic or chemical reactions (non-enzymatic browning and lipid oxidation).

* This paper is part of a FAO Technical Paper that is in preparation.

How much moisture does food contain when measured by standard methods (e.g. oven method, Karl-Fischer titration, infra-red balance, etc.) is not determinant. What is determinant is the amount of free water which allows microorganisms to grow or deteriorative reactions to set in.

When we speak about water activity in food we should bear in mind that we are integrating two aspects, the first is the physico-chemical aspect and the second is the effect of water activity on microorganisms.

2. Physico-chemical concept of water activity

From the physico-chemical point of view, water activity is the measure of a physical condition in a given environment, in equilibrium conditions, at total pressure and temperature constants. It can be analysed theoretically and by a number of methods until a certain extent can be predicted from equations.

From the point of view of the effect of water activity, the only way to know is by experimentation. Actually, it is the patient work of thousands of microbiologists that allows us today to use water activity as a reliable parameter in the study of food stability.

We can start our analysis of what is water activity from the physico-chemical point of view. From the study of dilute solutions, it can be seen that when a solution is formed, certain properties of the solution will differ from that of the pure solvent. These are:

(i) Partial pressure (lower in the solution than in the solvent)

(ii) Boiling point (higher in the solution than in the solvent)

(iii) Freezing point (lower in the solution than in the solvent)

(iv) Osmotic pressure (higher in the solution than in the solvent)

(v) Surface tension (lower in the solution than in the solvent).

All of the above are related to the amount of solute (or solvent) present in the solution and hence related to the amount of free unbound water. In ideal conditions, the changes in the different properties are equivalent and, in principle, could be used to measure water activity. However, in practice, change in partial pressure is the method more widely used when measuring water activity in food.

The activity in classical physico-chemistry in a solution is usually given as the ratio between fugacities:

$$a_1 = f_1 / f_1^o \quad [1]$$

where f_1 is the fugacity of the solution and $f^o{}_1$ is the fugacity of the solvent in the state of reference (pure liquid at a pressure of 1 atm and at the same temperature T of the solution).

The fugacity f is a corrected pressure. In ideal systems it is identical to partial pressure of the respective component. It is easy to see that in aqueous systems a_1 will be the water activity and equal to the ratio of partial pressures.

$$a_w \cong \frac{p_1}{p_1^o} \cong \frac{f_1}{f_1^o} \quad [2]$$

If we say that water activity of pure water is the unity, this value will be reduced when in a solution. If we measure water activity by the partial pressure of vapour, then we can define water activity as:

$$a_w = \left.\frac{\text{partial pressure of water vapour in a solution}}{\text{partial pressure of water vapour in pure water}}\right|_{P,T} \quad [3]$$

where both partial pressures have the same external total pressure (e.g. 1 atmosphere) and the same temperature (e.g. 18^{o}C). The expression [3] refers to water and water solutions. Nevertheless, the concept has been extended to complex materials such as soil, plant tissue and, of course, food. Then we can write

$$a_w = \left.\frac{\text{partial pressure of water vapour in food}}{\text{partial pressure of water vapour in pure water}}\right|_{P,T} \quad [4]$$

The concept we analysed in equations [3] and [4] is the thermodynamic concept of water activity. We should bear in mind that equations [3] and [4] are not general definitions of water activity (as often stated in publications) but a convenient way to express how a solution changed when referring to the pure solvent. Actually, other physical effects created by solutes can be more important in practice. For instance, the plasmolytic effect on microbial cells is due to the osmotic change, and the enhanced sensitivity of microbial cells to some substances is due to the reduction in surface tension.

It is generally accepted that water activity is the result of free unbound water existing in a food. However, the relationship between unbound water and water activity has not been determined yet. Bound water in food has been determined by sophisticated methods such as differential scanning calorimetry (DSC), nuclear magnetic resonance spectroscopy (NMR), X-ray or neutron diffraction spectroscopy and infra-red or Raman spectroscopy but these are not conclusive results. It seems that the main problem is to find an adequate definition of bound water. Any method devised to determine water binding depends on the definition of bound water. Different methods and definitions give more or less different results because they all rest upon different

aspects of the properties of water. So far, the concept of free water should be taken in a qualitative way.

Water activity can be related in theory to the main characteristics of a solution. We can write for a simple ideal solution (only one solute) the following equation:

$$a_w = \exp\left(-\phi \frac{v.m.M_1}{1\ 000}\right) \qquad [5]$$

where:

a_w = water activity of the solution
ϕ = osmotic (practical) coefficient
m = molality of the ion in solution
v = number of ions per molecule of solute
M_1 = molality of the solvent (0.018)

For an ideal solution of several solutes in one solvent we can write

$$a_w = \exp\left(-\phi M_1 \frac{v_i . m_i}{1\ 000}\right) \qquad [6]$$

where the i sub-index indicates the solute i. The deduction of equations [5] and [6] is given in Appendix 2. Equations [5] and [6] are the basis of any approach to the theoretical calculation of a_w in food systems. Water activity can also be calculated from isotherms (graphical relationship between water content and water activity at a given temperature) or from the empirical equations that adjust them.

Equation [5] can be expanded in series as follows:

$$a_w = 1 - (\phi\ M_1\ v).m + \frac{(\phi\ M_1 .v)^2 m^2}{2!} - \frac{(\phi\ M_1 .v)^3 m^3}{3!} + \ldots \qquad [7]$$

and thus, within a certain range, i.e. if $(\phi\ M_1\ v) << 1$ the following holds true

$$a_w \cong 1 - (\phi\ M_1\ v).m \qquad [8]$$

Lupin et al. (1981) demonstrated that equation [8] holds for moist salted fish and it is an acceptable approximation for pure solutions of NaCl. Recently, Favetto and Chirife (1986) have shown that the linear approximation given in equation [8] holds true for 15 non-electrolytes and 8 electrolytes in the range of interest of preserved food products, concluding that the accuracy of water activity estimation by this method satisfies the actual needs in food research.

Equation [6] can also be expanded in series as follows:

$$a_w = \exp\left(-\phi M_1 \sum \frac{v_i m_i}{1000}\right) =$$

$$= \exp\left(-\phi M_1 \frac{v_1 m_1}{1000}\right) \cdot \exp\left(\phi M_1 \cdot \frac{v_2 m_2}{1000}\right) \cdots$$

since

$$\exp\left(-\phi M_1 \frac{v_1 m_1}{1000}\right) = 1 - (\phi M_1 v_1) m_1 + \frac{(\phi M_1 v_1)^2 m_1^2}{2!} - \cdots$$

$$\exp\left(-\phi M_1 \frac{v_2 m_2}{1000}\right) = 1 - (\phi M_1 v_1) m_2 + \frac{(\phi M_1 v_1)^2 m_2^2}{2!} -$$

then

$$a_w = [1 - (\phi M_1 v_1) m_1] \cdot [1 - (\phi M_1 v_2) m_2] \cdots$$

Finally we can write:

$$a_w = \prod_{i=1}^{n} [\phi M_1 v_i) m_i] = \prod_{i=1}^{n} (a^o_w)_i \qquad [9]$$

where a^o_w is the molality of each component at its molality in the mixture. The equation

$$a_w = \prod_{i=1}^{n} (a^o_w)_i \qquad [10]$$

is also known as the Ross' equation (see Appendix 2).

3. Water activity and microorganisms

Water activity is a "mixed" property because the practical effect of a_w cannot be separated from the nature of the substances adjusting the a_w or those reacting to the imposed a_w. A microorganism can react differently to the same a_w in different media. Table 1 shows some examples.

Table 1 Influence of solute in minimun a_w for bacterial growth

	Minimum a_w for growth in		
	NaCl	Glucose	Glycerol
Clostridium perfringens	0.97	0.96	0.95
C. botulinum type E	0.97	-	0.94
C. sporogenes	0.945	0.965	0.935
Streptococcus thermophilus	0.985	0.986	0.947
S. lactis	0.965	0.949	0.924
Pseudomonas fluorescens	0.957	-	0.940
Vibrio parahaemolyticus	0.948	0.984	0.937

Taken from Sperber (1983)

As a matter of fact, microorganisms are alive and the reaction pattern of each one will be determined by the properties of its cytoplasmic membrane which is a result of complex functions of the entire physiology of the microorganisms. The microorganisms have mechanisms to adapt themselves, to a certain extent, to resist unfavourable environments. These mechanisms are activated when the microorganism is exposed to an unfavourable a_w. The reaction differs according to the a_w depressor. Most of the tables found in publications, including this work, refer to values that have been adjusted with NaCl.

In the case of preserved fish products, if salt (added or natural) is a usual component then general tables can be used. However, as there is a tendency to replace salt with other products in food, it should be borne in mind that different solutes may have different effects.

In these circumstances, water activity gives quick estimates on safety, stability and problems associated with preserved foods. In Table 2 we have a general picture of microbial inhibition according to the a_w value.

As an example, no deterioration can be expected at a_w = 0.75 from normal putrefactive bacteria (they cannot develop under a_w = 0.91) but salted fish can be spoiled by halophilic bacteria.

Table 2 Minimum a_w values at which deteriorative microorganisms can develop

Groups of microorganisms	a_w
Normal bacteria	0.91
Normal yeasts	0.88
Normal fungi	0.80
Halophilic bacteria	0.75
Xerophilic bacteria	0.65
Osmophilic yeasts	0.60

After Mossel and Ingram (1955)

Appendix 1 gives a more detailed table. Water activity can be related not only to the growth of microorganisms but also to the production of toxin (some of them can produce), sporulation and germination. Table 3 shows values related to *Clostridium botulinum*.

Table 3 Influence of a_w (NaCl) on germination outgrowing and toxin production in Clostridium botulinum

C. botulinum type	Minimum a_w for Germination	Growth	Toxin
Type C	-	0.98	0.98
Type E	0.93	0.97	0.97
Type A	0.93	0.96	0.95
Type B	0.93	0.96	0.94

Adapted from Sperber (1983) and Leistner et al. (1981)

Table 4 shows the minimum a_w for toxin production by some microorganisms.

Salted, salted-dried, smoked-dried and dried fishery products usually have a_w values equal or below 0.75. This means that the production of toxins, e.g. Clostridium botulinum, will be nil. However, toxins could be present if fish have not been properly handled and processed.

Nevertheless, in Table 2 and Appendix 1 it is easy to see that unless fish have a water activity below 0.60, different kinds of microorganisms can contaminate preserved fish products.

The survival of microorganisms at a given a_w is also the function of temperature. In Table 5 we can see the survival of Salmonellae sp. in fish meal at different temperatures.

Table 5 is interesting for two reasons. The first is that the driest product does not necessarily kill the undesirable bacteria first. Just the opposite is true. Reduced water activity has a preservative effect on many bacteria. The second reason is that in tropical environments (high temperature) the counts of Salmonellae sp. and other microorganisms are reduced quicker than in temperate and cold climates. The reduction dynamic is very important and, although not quite understood yet, it is necessary for determining proper process and storage procedures.

Other factors can interact in a given environment. In the case of food, we have a complex environment when compared with the culture media. Some variations may be expected regarding the minimum a_w for growth. For example, the minimum a_w for growth of S. aureus in the culture media is 0.86 (Appendix 1). However, when S. aureus was inoculated into a sterilised shrimp product, Troller and Stinson (1985) found that it could grow at a_w 0.91 but not at 0.89. A similar trend has been noted in smoked snoek (Theron and Prior, 1980).

Table 4 Minimal a_w for toxin production by microorganisms

Microorganisms	a_w
Clostridium botulinum	
Type C	0.98
Type E	0.97
Type A	0.95
Type B	0.94
Staphylococcus aureus	
Enterotoxin C	0.94
Enterotoxin B	0.90
Enterotoxin A	0.87
Mycotoxins	
Penitrem A	0.94
Citrinin	0.90
Patulin	0.90
PR-toxin	0.90
Cyclopiazonic acid	0.87
Roquefortine	0.87
Citreoviridin	0.86
Ochratoxin A	0.85
Griseofulvin	0.85
'S-toxin'	0.84
Aflatoxin	0.83
Penicillic acid	0.80

Leistner *et al.* (1981)

Other factors that play a role, together with a_w are pH, chemical preservatives, oxygen availability and redox potential. Some of the interactions have not been studied thoroughly till now but they are important in developing new types of preserved food and in understanding traditional ones.

What we are trying to say is that in practice when comparing the physico-chemical value of a_w with the overall effect caused by a substance (e.g. NaCl, sugar, etc.) on microorganism growth or deteriorative reactions,

Table 5 Influence of a_w and temperature on the survival of Salmonellae sp. in fish meal

a_w	Decimal reduction time (days) at 15°C	20°C	30°C
0.71	27	22	5
0.55	27	22	10
0.23	67	45	21

Sperber (1983)

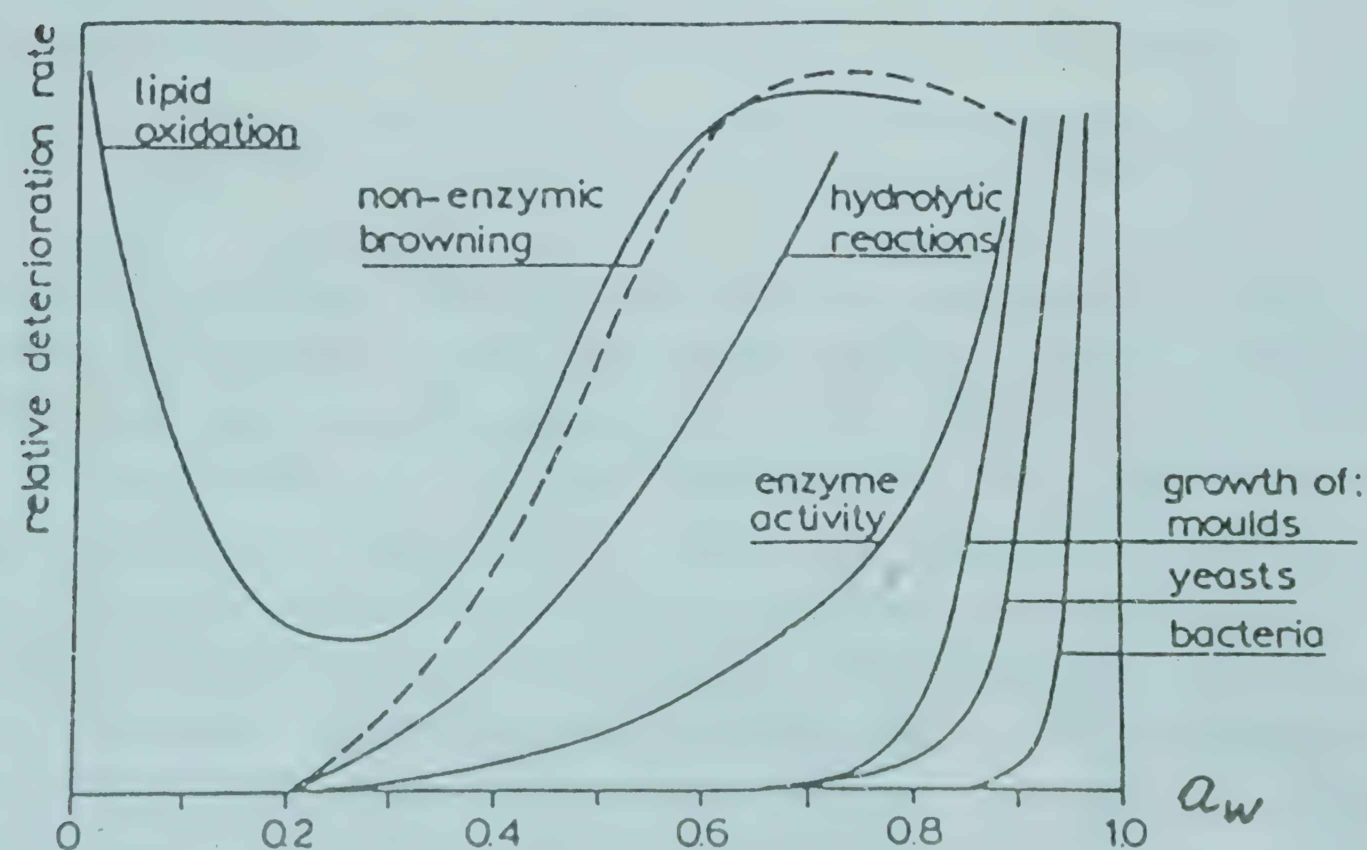
it will be very difficult to separate the influence of the a_w from the influence of the substances and the media involved.

4. Water activity and food deteriorative process not due to microorganisms

Water activity can also be related to other deteriorative processes in preserved products. With some reservation, a general figure (Figure 1) can be arrived at from data already published.

Since all food systems possess their own special features - chemical and physical - with respect to spoilage reactions, the information in Figure 1 can give only relative data. However, in general it supplies a part of the required insight into the different deterioration phenomena as a function of a_w. Starting from a_w = 1, a decrease in water activity slows down all

Figure 1 Generalised deteriorative reaction rates in food systems as a function of water activity (room temperature)



Labuza (1970)

types of chemical deterioration reactions and microbial growth until, at a certain level, all reactions are almost completely inhibited except for chemical oxidation of lipids, which is strongly favoured by a further decrease.

Suppose Figure 1 is used to analyse fish with an a_w value of 0.6. With this a_w value, deterioration due to action of bacteria, yeasts or moulds cannot occur. Nevertheless, the enzyme activity and the hydrolytic reactions will continue to some extent. Moreover, lipid oxidation and non-enzymic browning will continue at the same rate as in raw fish.

It is relatively easy to produce a product with a water activity of 0.6 but it will be very difficult to maintain it without deterioration during storage. How can we solve this problem? There are many alternatives but they usually involve additional cost. For example:

(a) to reduce the water content even more (and thus reduce the a_w) means an additional cost in energy and/or processing time;
(b) packaging (to prevent lipid oxidation);
(c) storing at low temperature (0 to 5°C);
(d) using additives (regulations permitting).

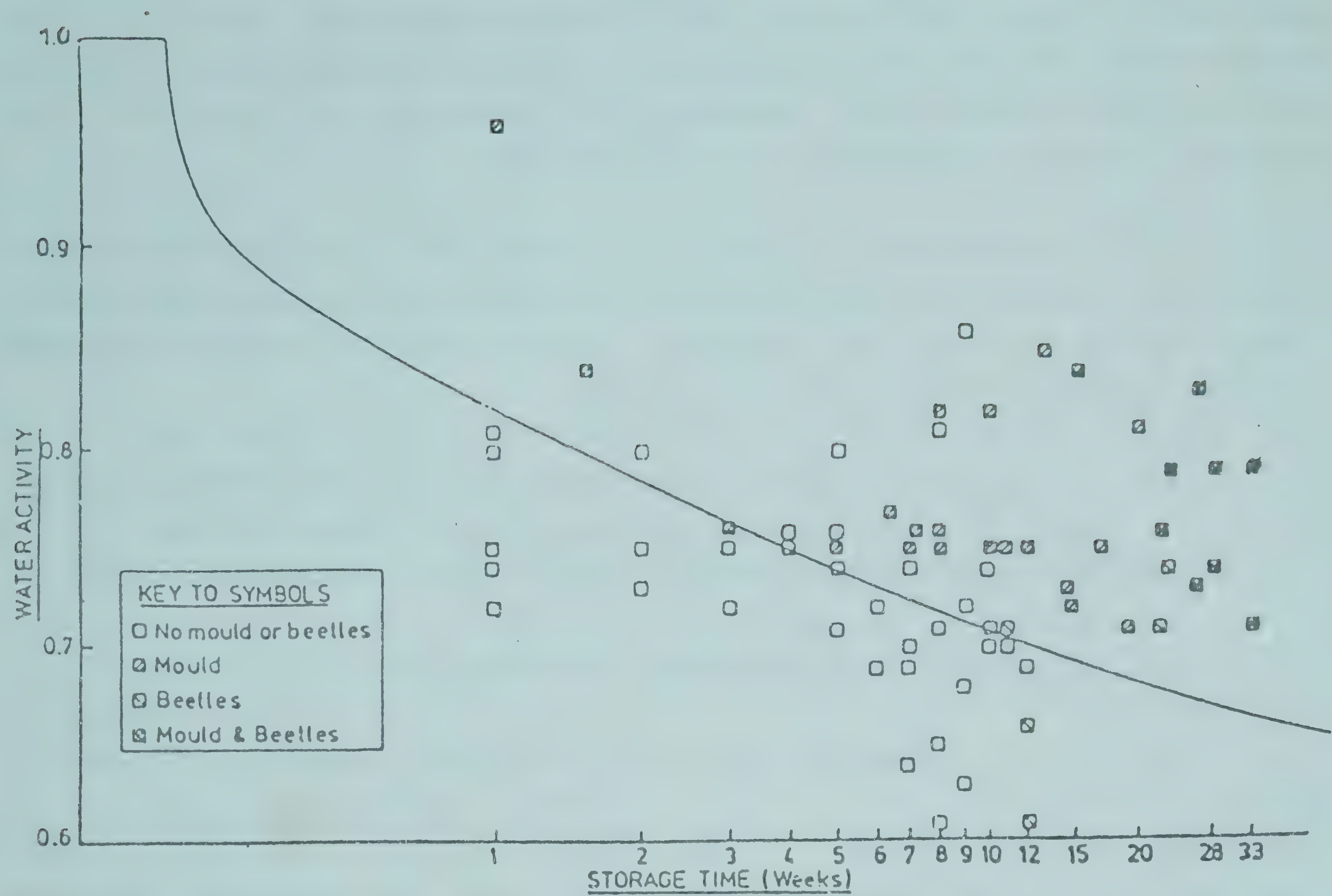
On the whole, developing countries solve this problem by continuing to sun dry until a very low a_w value is reached. But again, a very low a_w value leads to other problems. In smoked-dried fish, fragility increases with the lowering of a_w and pieces of flesh can separate into fragments. This can result in hindering trade, lowering quality, etc. The problem of fragility has not been included in Figure 1. Contrary to other dried food products, mechanical fragility is important in dried or cooked fish products since longitudinal contraction (along the backbone) is higher than transversal contraction. This in turn creates mechanical tensions that may lead sections of the fish to break off (especially in the tail and head sections).

Another very important aspect in developing countries is insect attack on preserved fish products (FAO, 1981). This is usually a result of improper storage after processing. In Figure 2, we can see the conclusions of Doe, Poulter and Curran (1981) after they studied the keeping-time of seven species of salted-dried fish in Sri Lanka during storage.

Most of the samples with an a_w value above the curve in Figure 2 had colonies of mould present, only those samples which were smoked or heavily infested with beetles did not show any mould growth. In each instance fish samples with an a_w value below the curve in Figure 2 had no mould. However, a few samples did show beetle infestation.

As a matter of fact, a good relationship between the fate of insect infestation and a_w value in preserved fish does not exist and further studies

Figure 2   Occurrence of beetles and/or mould (Sporendum epizoum) infestation during storage of salted-dried fish as a result of the water activity value of the samples



in this field are necessary. A_W will be of no significance to a full grown insect but is extremely significant when dealing with egg laying, egg hatching and probably larvae development.

5. How the concept of a_w can help in fish processing, storage and inspection

Staple foods in developing countries are usually those foods with low water activity. This category also include cheap foods. Moreover, a preservation method that preserves cheap food and is cheaper than the methods already used to preserve food with lower a_w value is not foreseable in the near future unless it is a method based on lowering the a_w.

Many developed countries (including those in the European Common Market) began using the a_w concept in their food regulations some 5 or 10 years ago (Rodel and Leistner, 1982). Developing countries which have more need of this concept have food regulations (if they have any at all) based on water and salt content, dry matter, etc., often confusing any attempt to improve or control the quality of the product.

Very often attempts to develop new foods in developing countries are merely kitchen exercises because they do not use the a_w concept. Whereas it is often expensive and time-consuming to test a new food to see whether it is safe, edible and storable by applying time-consuming and complicated microbiology tests, the comparatively cheap and easy to measure a_w can tell us if we are on the safe side or not.

The a_w concept condenses the work done over the years by hundreds of microbiologists who analysed the resistance of microorganisms in different water activity conditions. Moreover, the a_w value can indicate the kind of problem we are likely to run into.

In Table 6 we can see the relative importance of water activity for different kinds of processes when compared with other process variables such as temperature. Table 6 is also useful to identify the process (or product) where water activity is important.

Table 6 deserves a careful analysis because it is always useful to differentiate between very close processes such as salting and curing (or ripening). As a matter of fact, in Table 6 only the single processes are listed but in practice we can find products by combining processes, e.g. salted-dried fish, smoked-dried fish, etc.

Only one combined process, smoking-drying, was included in Table 6. It is easy to see why the fundamentals of the combined process are mainly determined by the drying step. The drying step is more important than the smoking step for the stability of food when the process is combined. The reason for this is that the drying process reduces the water content and thus the water activity.

Although Table 6 can be slightly modified when analysing the storage of new products, the a_w importance will not change. This means that a_w can be used not only to control the process but also to control storage and the characteristics of the product itself in cases where a_w is the main parameter.

6. How a_w relates to preserved fish products

Each preserved fish product can be related to a_w. However, general relationships are still being studied. The relationship will be useful for standardising preserved fish products, e.g. easy quality and sanitary control and developing safer preserved fish products. There is more than one way to study the relationship between water activity, solute and moisture content in preserved fish products. Here, we are going to use an approach based on equations [5] and [6] because they allow straight line representations that are easy to interpret and fit.

6.1 Wet salted fish

Wet salted fish (also called pickled fish) is popular in many countries around the world. In Europe, there are many well-known products of this type based on herring, anchovy and sardine. Similar products are found in Asia, Latin America and Africa. Even though the use of salt (NaCl) as a preservative has been criticised recently, it is unlikely that developing countries will find another a_w depressor that is cheaper and safer.

Table 6 Processes used in fish processing and parameters on which they are based

Parameters \ Process	Canned/Sterilized	Chilled	Freezing	Drying	Curing (Ripening)	Salting	Sugar Addition	Acidification	Fermentation	Smoking	Smoking-Drying	Oxygen Removal	Interm.Moist.Foods
High temperature	x	*	*	*	*	o	*	o	*	*	*	*	*
Low temperature	*	x	x	o	*	*	o	*	*	*	o	*	*
a_w	*	*	x	x	x	x	x	o	x	*	x	o	x
pH	*	*	o	*	*	*	x	x	x	*	*	*	*
Eh (Redox potential)	*	*	*	o	*	*	*	*	*	*	*	x	*
Preservatives	*	*	*	*	x	*	*	*	x	x	*	*	x
Competitive flora	o	o	o	o	*	o	o	*	x	o	o	*	*

x - main parameter

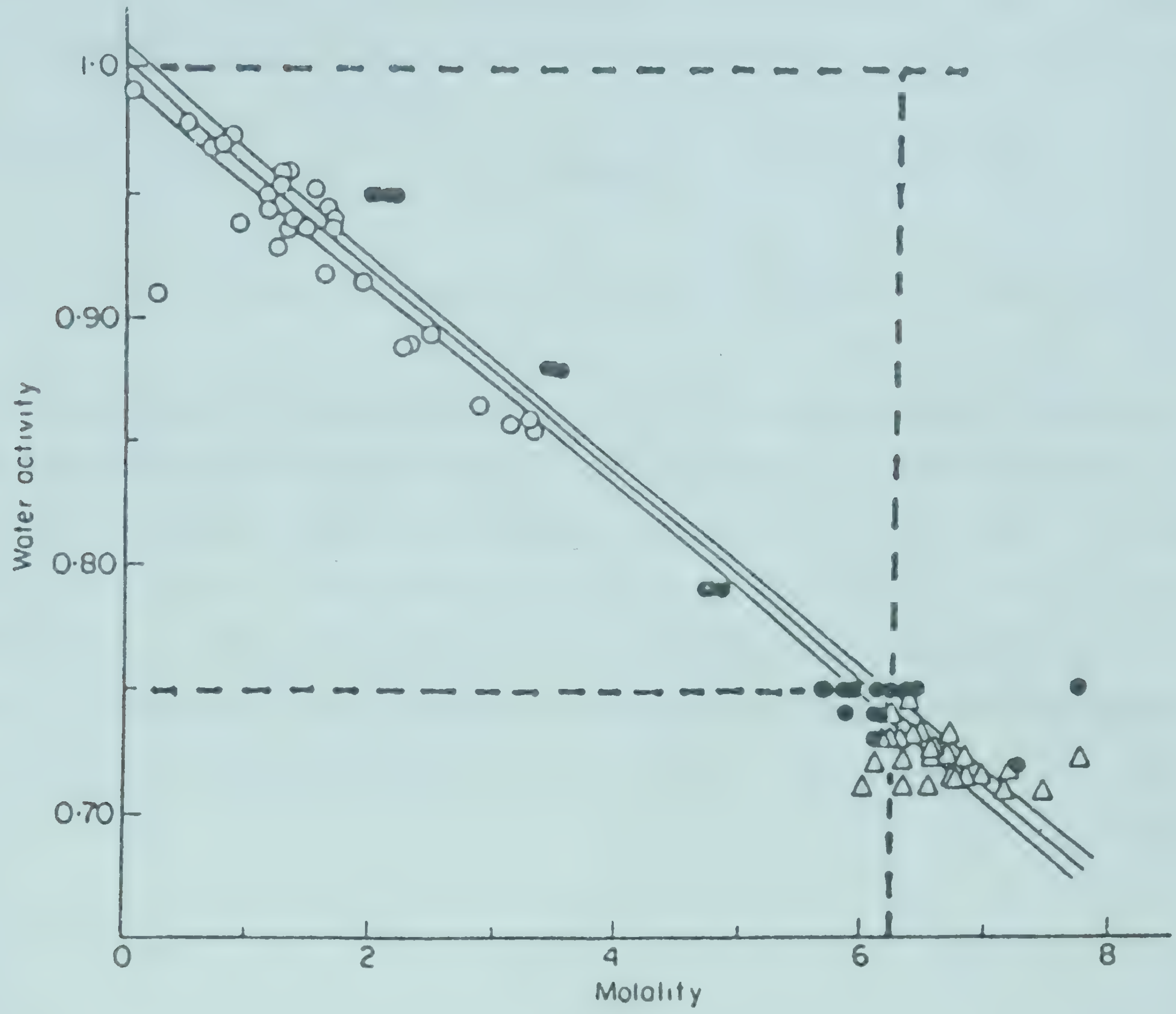
* - secondary parameters

o - parameter generally not important in this process

Adapted from Leistner et al. (1981)

The relationship between water activity and salt content in wet salted fish is shown in Figure 3.

Figure 3 Water activity vs. NaCl molality in fish products



Experimental points correspond to salted • cod, o mullet roe, anchovy
After Lupin et al. (1981)

The line of Figure 3 corresponds to the equation

$$(a_w)sf = a^o_w - bm = 1.002 - 0.042\ m \qquad [11]$$

where:

$(a_w)sf$	:	water activity of salted fish product
m	:	molality of solute (NaCl)
a^o_w	:	water activitiy at zero molality
b	:	straight line slope.

Although the values given here are rounded to the third decimal figure, only the second decimal figure is significant in practical calculations.

The NaCl molality (m) is calculated considering it to be in true solution in the total water content of the product.

The molality of NaCl can be easily calculated from the percentages of NaCl and moisture content determined in the usual way. The equation that relates molality to salt and water percentages is:

$$m = 17.111 \frac{\%\ \text{NaCl}\ (w/w)}{\%\ H_2O\ (w/w)} = 17.111 \frac{Ms}{Mw} \qquad [12]$$

where Ms = mass of NaCl (g) and Mw = mass of water (g).

It is clear from equations [11] and [12] that both percentages of NaCl and water will be necessary to define the a_w of the wet salted product. Salt or water content alone will not be sufficient to define the stability of the product. If we are working with this type of product, maybe the quickest and cheapest way to estimate water activity is by measuring NaCl and water content as what is done in some countries to assess a_w in products like salami, bacon, ham and, of course, wet salted herring and anchovies (personal com.; Debeverre, 1986).

The relationship between water activity and NaCl in pure solution is given in [13]:

$$a_w = 1.007 - 0.040\ m \qquad [13]$$

which means that in practice water acitivty of a salted moist product is a result of the NaCl concentration.

As the NaCl in pure water reaches saturation at around 6.2 m, the minimum a_w attainable by salting is in theory around 0.75. This is shown in Figure 3. Nevertheless, Figure 3 shows some experimental points with an a_w below 0.75 mostly corresponding to heavily-pressed wet salted anchovy. It seems that pressing exerts a "drying" action.

Equations [11] and [13] are based on equation [8].

6.2 Dried fish

In many countries, due to lack of salt or tradition, fish is dried (usually sun-dried) until it reaches a state of dryness that allows it to keep for a relatively long time. Fish is also dried mechanically in some developed countries. Dried fish is one of the foods with the highest protein content. Properly dried fish can contain up to 80% of its weight in protein.

In this case, water activity is lowered due to the action of fish muscle. However, the NaCl naturally contained in fish also plays a significant role as it becomes concentrated during water loss and thus contributes to the total lowering of water activity. In drying, the lowering of water activity normally begins after the first stage of drying. During the first stage, when

fish react like any other wet body, the water activity of the fish is likely to be that of pure water. This means near the unity.

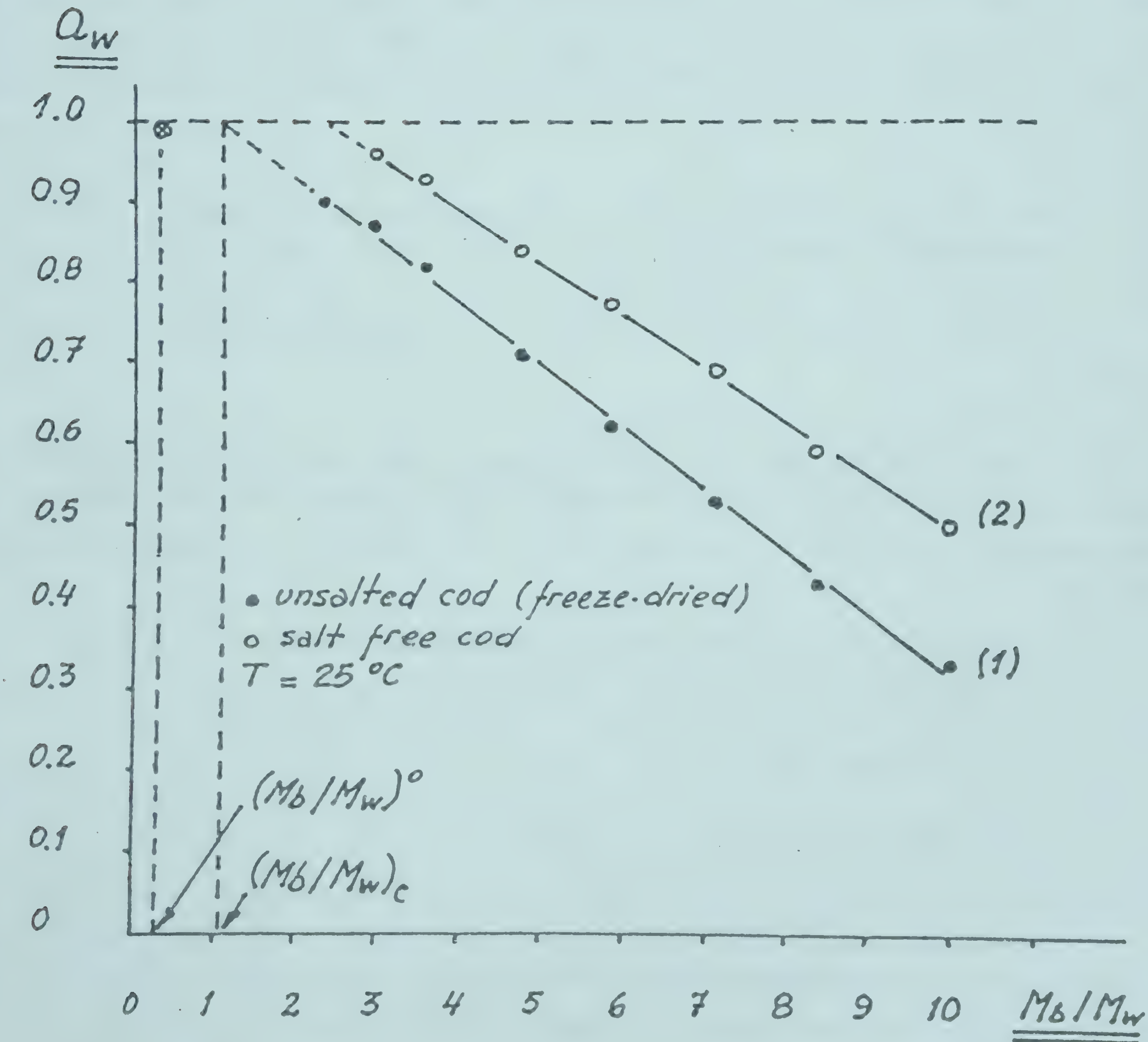
In Figure 4 we can see the representation of a_w versus Mb/Mw where:

Mb = salt-free, fat-free dry mass

Mw = mass of water.

In this case, Mb represents a sort of concentration measure of the fish muscle. We can also define Ms as the mass of salt content in the fish muscle, e.g. unsalted cod Ms/Mb = 0.05 (38).

Figure 4 Relationship between a_w and Mb/Mw in (1) dried cod (only natural NaCl) and (2) dried cod (freeze-dried) pure muscle (discounting NaCl effect)



Experimental data taken from Doe et al. (1982)

Experimental points of Figure 4 can be fitted by straight lines. The equation for dried cod containing natural salt is:

$$a_w = 1.084 - 0.077\ (Mb/Mw);\ (r = 0.998) \qquad [14]$$

Equation [14] is valid for

$$1.5 \leq (Mb/Mw) \leq 10 \qquad [15]$$

For (Mb/Mw) = 10, a_w is approximately 0.32, which exceeds the practical range of dried fish (usually around a_w = 0.60).

As can be seen from Figure 4, this way of representing food isotherms also has the advantage of clearly defining the "critical relationship" (Mb/Mw)c, the point at which the unsalted fish muscle (containing only natural NaCl) starts to exert some action.

The critical point is defined as:

$$1 = 1.084 - 0.077\ (Mb/Mw)c \qquad [16]$$

or

$$(Mb/Mw)c = 1.091 \qquad [17]$$

Border condition taken in [15] was 1.5 instead of 1.091 for safety purposes.

The effect of NaCl can be discounted from the total a_w in order to obtain a representation of the influence of the fish muscle alone, without the influence of the naturally contained NaCl. The straight line equation in this case is:

$$a^o_w = 1.160 - 0.066\ (Mb/Mw) \qquad [18]$$

valid in the range of

$$2.5 \leq (Mb/Mw) \leq 10 \qquad [19]$$

Again, we can define a "critical relationship". The upper limit of the validity of [18] corresponds appoximately to an a_w of 0.5 so equation [18] represents the isotherm inside the range of practical values.

From Figure 4 or equations [14] and [18] the importance that NaCl plays in the lowering of a_w in unsalted fish is very clear. If this natural NaCl is lowered, as what happens when fish is improperly dried (dried at high temperature with thermal denaturalisation of proteins and release of liquid

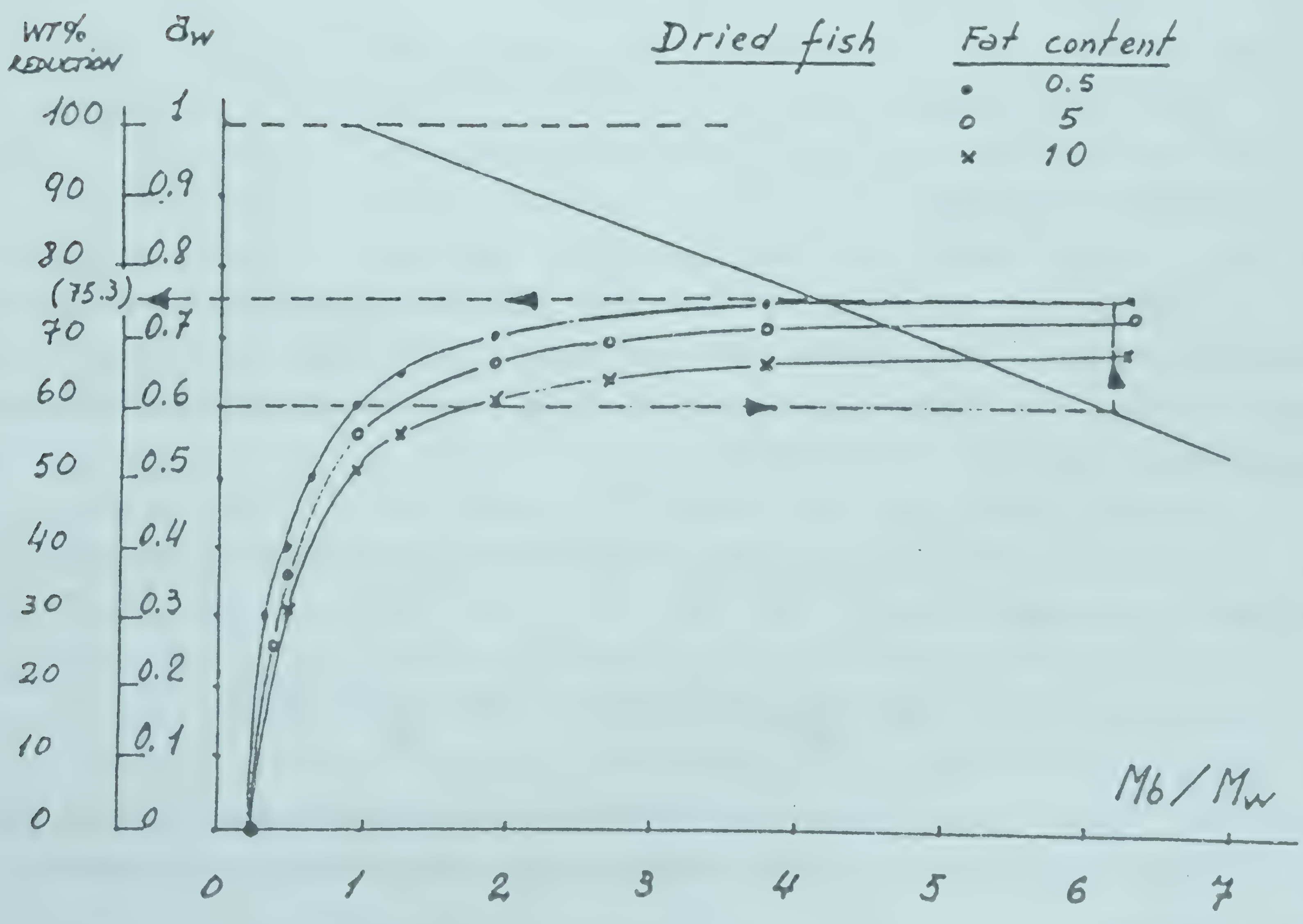
containing NaCl instead of evaporation), the final product will have, for the same weight reduction, a higher a_w than the properly dried product and will be more unstable from the a_w point of view.

Equations [14] and [18] are easier to understand and to work with than classic isotherms. However, at field level where most of these products are produced in tropical countries there are no facilities for measuring Mb, Mw and Ms. For this reason, an attempt has been made to find a relationship between a_w and weight reduction during drying. The graphical way of estimating a_w can be seen in Figure 5.

It is possible to extract useful information for practical purposes from Figure 5.

For example, it shows that the weight reduction in lean fish should be higher than in fatty fish to achieve the same a_w. Dried fish with only a 50% reduction in weight (or even 60% in the case of lean fish) will spoil in the same way as fresh fish (after the surface effect of drying is gone). From Figure 5 it is possible to deduct practical rules for drying and get a rational answer to the old problem of dried fish stability vs. increased cost due to weight reduction.

Table 5 Graphical estimation of a_w in fish drying from percentage of weight change for (•) lean fish (0.5% fat content), (o) medium fatty fish (5% fat content) and (x) fatty fish (10% fat content)



Equation [14] has been found valid in a number of published experimental data. However, it should be mentioned that there are published results

that are not in agreement. In practice, it is difficult to test equation [14] with published data since many authors have not published the fat and/or natural salt content of their samples.

It should be noted that the a_w of dried fish can be obtained by applying the Ross' equation (see equation [2] and Appendix 2). In this case:

$$a_w = a_w(NaCl) \cdot a^o_w \qquad [20]$$

where:

$a_w(NaCl)$ = water activity of pure NaCl solutions (equation [13])

a^o_w = water activity of "desalted" fish muscle (equation [18])

However, equation [14] can be used in this case since Ms is fixed and varies only because of evaporation.

Finally, returning to Figure 4, it is clear that a second border condition for the upper part of the straight line equation can be established for dried fish as:

for $(Mb/Mw) \leq 1.5$ $\quad a_w = 0.99$ (fresh fish; Chirife and Ferro-Fontan, 1982) [21]

and

for $(Mb/Mw) \leq 2.5$ $\quad a_w = 0.99$ [22]

for unsalted fish muscle.

6.3 Salted-dried fish

The a_w of salted-dried fish can be studied by applying the Ross' equation mentioned above. The main difference is that NaCl content in salted-dried fish will be higher than in unsalted fish and can take any value from the natural NaCl content to saturation.

From equation [9] it is clear that we can combine equations [12], [13] and [18] to obtain.

$$a_w = [1.007 - 0.684 \left(\frac{Ms}{Mw}\right)] \times [1.160 - 0.066 \left(\frac{Mb}{Mw}\right)] \qquad [23]$$

where the first factor of the 2nd hand is the contribution of NaCl and the second factor is the fish muscle contribution. The border conditions of equation [23] are:

$$(i)\quad 0.075 < \frac{(Ms)}{Mw} \leq 0.36;\ \text{saturation} \qquad [24]$$

$$\text{for} \quad \frac{(Ms)}{Mw} < 0.075;\ a_w(NaCl) = 0.99 \qquad [25]$$

$$\text{for} \quad \frac{(Ms)}{Mw} > 0.36;\ a_w(NaCl) = 0.75 \qquad [26]$$

$$(ii)\quad 2.5 \leq \frac{(Mb)}{Mw} < 10 \qquad [27]$$

$$\text{for} \quad \frac{(Mb)}{Mw} < 2.5;\ a_w = 0.99\ \text{(fresh fish)} \qquad [28]$$

Conditions [27] and [28] repeat the conditions [19] and [22] respectively.

A family of straight lines can be generated in this case by fixing the Ms value. These types of isotherms are called isohalic isotherms (mass of NaCl and temperature constant).

A point of discussion is the suitability of using the Ross' equation since it is clear that fish muscle is not a solute in an ideal solution as is theoretically required. In his paper, Ross (1975) suggested that in the presence of non-solute materials an equivalent water activity factor may also be assigned to each non-solute on the basis of its sorption isotherm, considering that all the water is sorbed in each non-solute separately. This concept has been applied by various authors. In the case of salted-dried fish, it has been applied by Doe <u>et al</u>. (1982), Poulter <u>et al</u>. (1982) and Curran and Poulter (1983), with acceptable experimental results.

Chirife <u>et al</u>. (1985, 1986) have recently published an experimental study on ternary systems with ionic and non-ionic solutes and casein (non-soluble). The results have shown that Ross' equation can be used directly, with results that depart on an average of 12% from the experimental values. The predicted results using the Ross' equation are always higher than the experimental value of a_w, so the prediction is safe in the sense that the actual product will have an a_w value lower than predicted. The authors also have shown that the prediction could be improved, taking into account that water strongly bounded to casein is not available to dissolve the solutes. This correction has not been taken into account when applying equation [14] or in the papers of Doe <u>et al</u>. (1982), Poulter <u>et al</u>. (1982) and Curran and Poulter (1983) mentioned previously. In any case, equation [14] or the method suggested by Doe <u>et al</u>. (1982) is adequate as a good approximation since fish muscle is very complex and it will be difficult and maybe impractical to separate all the possible effects. For example, it is well-known that muscle phosphates lower the solubility of NaCl, so the actual contribution of NaCl to the reduction of water activity at saturation will be lower than that of pure solutions.

Figures like Figure 5 can be constructed (Ms constant) in order to obtain indications on how the process of salting-drying can be controlled by weight reduction. The figure will be different, depending on the Ms in the fish muscle at the end of the salting stage.

6.4 Smoked-dried fish

Smoked-dried fish could be considered prima facie dried fish because of its water activity since the main reason for its stability is in the drying process. Smoked fish (without drying) currently found in Europe has a high water content and consequently a high water activity value. Its keeping time and safety depends mainly on storage temperature.

Nevertheless, the smoke effect should not be disregarded in smoked-dried fish. The smoke compounds have bacteriostatic action and reinforce the action of a low a_w value on the fish's surface. In Figure 2 the samples that appear above the curve with "no mould no beetles" have been smoked.

Smoked-dried fish leads to the question of water activity on the surface of fish. As a matter of fact, the contamination of preserved fish (halophilic bacteria, moulds) begins on the surface. More research work is needed to clarify this phenomena.

In Table 7 we can see the a_w of some smoked-dried fish products from Uganda.

Table 7 Water activity in smoked-dried and sun-dried products, samples taken from Kampala markets, 1984, Uganda

Type of product	a_w
Smoked-dried Nile Perch (*Lates niloticus*)	0.78
Smoked-dried *Bagrus* spp.	0.72
Smoked-dried *Tilapia* spp.	0.74
Smoked-dried *Clarias* spp.	0.74
Smoked-dried *Protopterus* spp.	0.75
Sun-dried *Engracypris* spp.	0.74
Sun-dried *Haplochromis* spp.	0.72

Measurements taken around 10 days after production
Data from M. Masette (Fisheries Department), Uganda

Table 7 in general repeats the results observed in a_w measurements of other commercially smoked-dried fish products of Africa, i.e. that the water activity of these products is around 0.75. This level of a_w is in practice a compromise between stability (moulds, fragility, etc.), appeal to the consumers and weight reduction.

6.5 Marinades

Marinades is a fish product preserved by the simultaneous action of salt and acid (vinegar) (Meyer, 1965). For this reason, it is a good example of combined action. This means a product whose keeping time is a function of a_w and other factors (in this case pH).

Marinades is a typical European product although similar products are prepared everywhere (e.g. Latin American 'sebiche' which has lemon juice - citric acid - instead of vinegar).

Figure 6 shows the combined action of a_w and pH on microorganism growth.

Generally, as the a_w of a food is lowered, the pH limits within which growth will occur are narrowed. These effects have been described by Ohye and Christian (1966) for C. perfringens and by Troller (1973) for S. aureus. Similar effects occur with yeasts and moulds (Troller, 1980).

In case of marinades (or similar products), a_w can be estimated by using the equation [13] and the pH with a_w standard pH meter. Both measures can tell us if we are on the safe side or not of Figure 6. However, a complete description of the phenomena is, however, still lacking. Enzymatic hydrolysis of flesh becomes the main problem in marinades in the safe (from the bacterial point of view) zone of Figure 6. The hydrolysis is due to the intrinsic enzymes of the fish muscle, acid creates an acid environment in which cathepsin has its optimal range of around pH 4.5.

In European marinades, a_w ranges from 0.96 to 0.98 and pH is around 4.10. High concentrations of NaCl and acetic acid (vinegar) tend to suppress hydrolysis rather than the reverse. As can be seen in Figure 6, European marinades are on the borderline of the 'safe' zone as regards bacteria. Nevertheless storage time is dictated by the extent of hydrolysis. Temperature then becomes an important factor. Keeping time of marinades stored at 27°C does not exceed 3 weeks but marinades stored at cooler temperatures (4 to 6°C) keep a long time (several months) (Meyer, 1965).

The growth of moulds and yeasts in commercially available marinades is not ruled out and that is the reason why jars and recipients are filled to the top and tightly sealed. In some countries, where it is allowed, additives are also incorporated in the brine. These anti-fungal or anti-mycotic agents are

Figure 6 Effect of a_w and pH on microorganism growth (bacteria, moulds and yeasts)

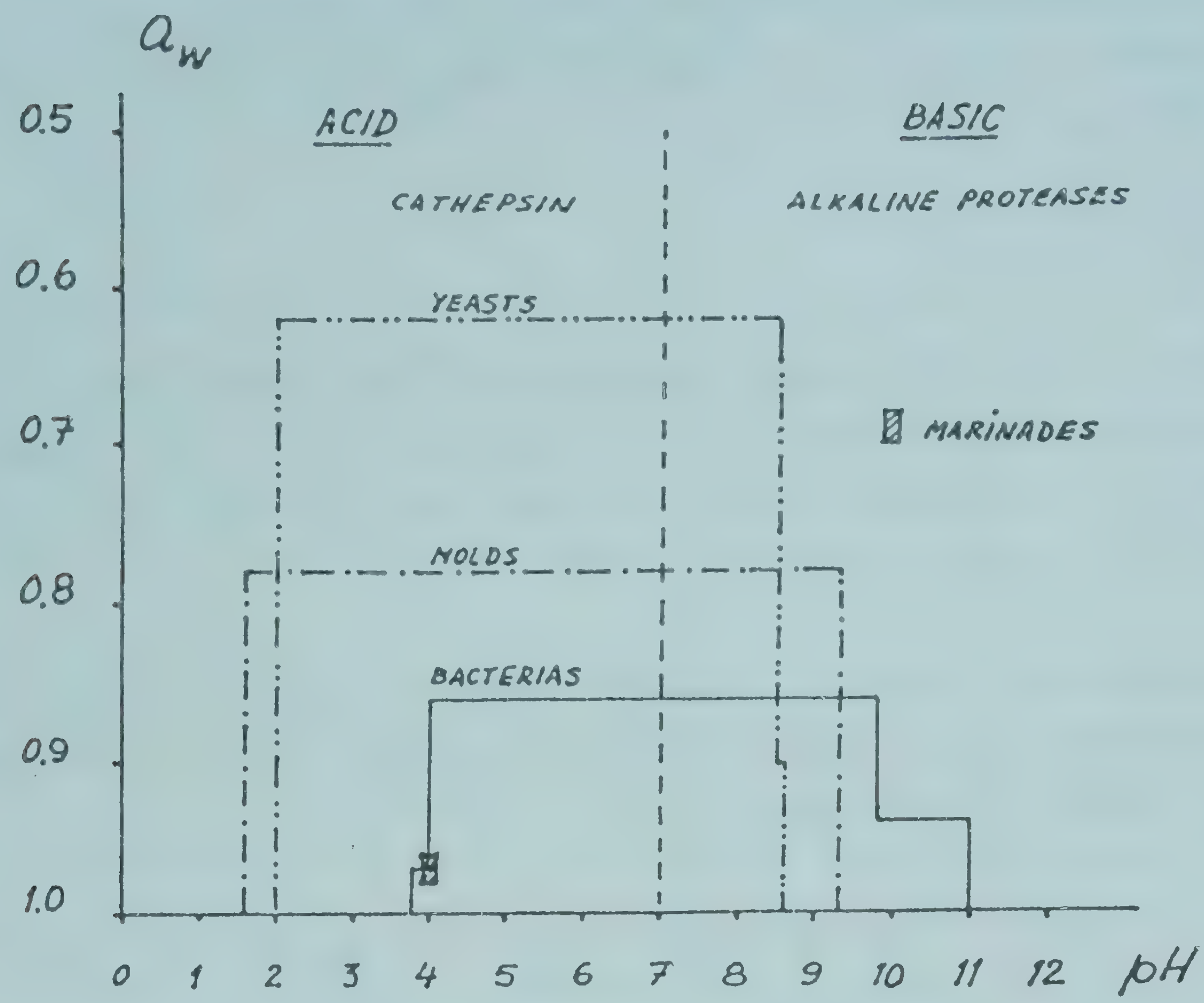


Figure based on data published by Mossel (1976), Troller (1980) and Resaino et al. (1982)

chemicals that interfere with or prevent mould growth. Sometimes they may occur naturally in some foods, e.g. some organic acids and essential oils.

A number of chemicals that have anti-mycotic properties are used in foods. They include sorbic acid and sorbate, propionic acid and propionate, benzoic acid and benzoates and parabens. Fortunately for the marinades, acetic acid (vinegar) and its derivatives are examples of these natural substances. The phenolic anti-oxidants, particularly BHA, also have anti-mycotic properties (we should remember that phenols are deposited in fish during smoking).

There is an additional type of product that can fall into this category. It is fermented fish processed as biological fish silage. In this fish, a lactic fermentation is carried out using a source of carbohydrates first mixed thoroughly with minced fish. The objective is to produce lactic acid that in turn will lower the pH and produce the action of the proteolytic enzymes of fish muscle. In this case, we have a reduction in the pH, a certain amount of NaCl (more or less in the same order as in marinades), anti-microbial and anti-oxidant chemicals produced during the lactic acid fermentation and competitive flora (*Lactobacillus* spp.). My practical experience indicates that this type of product is not free of mould growth unless vinegar (acetic acid) is added.

6.6 Frozen fish

Frozen fish is in a way a preserved fish product where the chief control parameter is temperature. Water activity plays only a secondary role. In

present frozen fish products, it has been proved that water activity is determined by temperature (Storey and Stainsby, 1970; Schenberger, 1977).

The equation that relates water activity to temperature below $0^{o}C$ in frozen fish products is:

$$a_w = \exp\ [-9.702.10^{-3} \cdot (273.16-T) - 5.2\ 10^{-6} \cdot (273.16-T)^2] \quad [29]$$

where

T = absolute temperature (^{o}K) (always 273.16 > T)

The equation [29] was obtained by using only thermodynamic considerations (see Appendix 2.d) but it agreed with experimental determinations because water crystallizes as pure ice in frozen fish. This means that for a given temperature below the crystallisation point of a solution, the water activity is a constant, independent of the solute (e.g. tissue salts and compounds dissolved in the still unfrozen water).

The relationship between microorganism growth and water activity below $0^{o}C$ is shown in Table 8. Of course, it is easier to measure temperature than water activity in frozen fish although the concept of water activity can help here to understand deteriorative problems in frozen foods.

Table 8 Minimum growth temperature and a_w ranges for microorganisms below $0^{o}C$

Group of microorganisms	Temperature (^{o}C)*	a_w**
Psychrophilic bacteria	-5 to -10	0.952 - 0.907
Yeasts	-10 to -12	0.907 - 0.889
Moulds	-15 to -18	0.863 - 0.836

* From Schmidt-Lorenz (1970)

** Calculated from equation [29]

Table 8 is useful not only for identifying what kind of problems can be foreseen with microorganisms at a low temperature but also for preventing freezer burn. As a matter of fact, in the equilibrium, the a_w of a frozen food relates to the equilibrium relative humidity in the storage room as follows:

$$ERH = a_w.100 \quad [30]$$

The idea of equilibrium is underlined because the equation is valid only in equilibrium conditions. It is just variations of equilibrium that produce freezer burn.

In the case of

$$a_w \cdot 100 > \text{E.R.H. (storage room)} \quad [31]$$

dehydration will occur which will lead to freezer burn.

From a general point of view, a_w in frozen foods is not low enough to prevent enzyme catalyzed reactions, non-enzymatic browning or auto-oxidation. Even though temperature lowers the rate of deterioration, frozen foods deteriorate even in very low temperatures such as -100^{o}C. Nevertheless, temperatures between -18 and -30^{o}C are, fortunately, quite acceptable for commercial purposes.

As in other preserved fish products like salted or dried fish, we should use the right packaging and/or additives if we want to prevent oxidation. Freezer burn can also be prevented with proper packaging.

6.7 New preserved fish products

Many new preserved fish products have been suggested over the last few years mainly due to the necessity (a) for cheap foods (cheap not only from the point of view of production but also storage), (b) to use under-utilised species, (c) to overcome problems associated with traditional preserved fish products, and (d) to supplement nutrition (e.g. nutrition based only on cereals) or a combination of these factors.

Some examples of these studies are: developing a product based on Alaska pollack, salt and glycerol by Jamieson (1977) developing dehydrated salted fish/soya cakes by Moledina et al. (1977), or developing fish-starch flakes by Venugopalan and Govindan (1967).

All of these new preserved products can be studied from the point of view of a_w. As a matter of fact, it is also possible to obtain the isotherms from new products. The Ross' equation can be used to predict the a_w of the mixtures but direct measurements are advisable when developing complex foods.

Although much effort has been made in developed countries over the last 10 to 15 years to obtain new a_w depressors and additives, it is unlikely that this field can be really enriched if today's available basic knowledge is not used to study other popular preserved foods already existing in developing countries and still not well-known.

It took centuries before people developed these preserved products and surely they have the best compromise between economy, nutrition, stability and taste.

This paper was written with the aim and hope that it serves not to emulate the Western developed countries way of producing new foods but to help people in developing countries to understand and improve their own preserved fish products.

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APPENDIX 1

Minimal a_w for multiplication of microorganisms associated with foods

A_w	Bacteria	Yeasts	Moulds
0.98	C. botulinum C, Pseudomonas*	-	-
0.97	C. botulinum E, Pseudomonas*, C. perfringens*	-	-
0.96	Flavobacterium, Klebsiella, Lactobacillus*, Proteus*, Pseudomonas*, Shigella	-	-
0.95	Alcaligenes, Bacillus, Citrobacter, C. perfringens, C. botulinum A, B, C, Enterobacter, Escherichia, Propionibacterium, Proteus, Pseudomonas, Salmonella, Serratia, Vibrio	-	-
0.94	Bacillus*, C. botulinum B*, Lactobacillus Microbacterium, Pediococcus, Streptococcus*, Vibrio, Enterobacter		Stachybotrys
0.93	B. stearothermophilus*, Micrococcus*, Lactobacillus*, Streptococcus		Botrytis, Mucor, Rhizopus
0.92	-	Pichia, Rhodotorula, Saccharomyces*	-
0.91	Corynebacterium, Streptococcus		
0.90	B. subtilis, Lactobacillus*, Micrococcus, Pediococcus, Staphylococcus (S. aureus anaerobic), Vibrio*	Hansenula, Saccharomyces	
0.88	-	Candida, Debaryomyces, Hanseniaspora, Torupolis	Cladosporium
0.87	-	Debaryomyces*	-
0.86	Micrococcus*, Staphylococcus (S. aureus aerobic), Vibrio (V. costicolus*)	-	-
0.84	-	-	Alternaria, Aspergillus*, Paecilomyces
0.83	Staphylococcus*	Debaryomyces*	Penicillium*

A_w	Bacteria	Yeasts	Moulds
0.81		Saccharomyces*	Penicillium
0.79	-	-	Penicillium*
0.78	-	-	Aspergillus Emericella
0.75	Halobacterium, Halococcus (halophilic bacteria)	-	Aspergillus*, Chrysosporium
0.62	-	Saccharomyces*	Eurotium*
0.61	-	-	Monascus (Xeromyces)

* Some isolates

Leistner et al. (1981)

Leistner and Rodel (1975)

Troller (1979)

APPENDIX 1

Minimal a_w for multiplication of microorganisms associated with foods

A_W	Bacteria	Yeasts	Moulds
0.98	*C. botulinum* C, *Pseudomonas**	-	-
0.97	*C. botulinum* E, *Pseudomonas**, *C. perfringens**	-	-
0.96	*Flavobacterium*, *Klebsiella*, *Lactobacillus**, *Proteus**, *Pseudomonas**, *Shigella*	-	-
0.95	*Alcaligenes*, *Bacillus*, *Citrobacter*, *C. perfringens*, *C. botulinum* A, B, C, *Enterobacter*, *Escherichia*, *Propionibacterium*, *Proteus*, *Pseudomonas*, *Salmonella*, *Serratia*, *Vibrio*	-	-
0.94	*Bacillus**, *C. botulinum* B*, *Lactobacillus* *Microbacterium*, *Pediococcus*, *Streptococcus**, *Vibrio*, *Enterobacter*		*Stachybotrys*
0.93	*B. stearothermophilus**, *Micrococcus**, *Lactobacillus**, *Streptococcus*		*Botrytis*, *Mucor*, *Rhizopus*
0.92	-	*Pichia*, *Rhodotorula*, *Saccharomyces**	-
0.91	*Corynebacterium*, *Streptococcus*		
0.90	*B. subtilis*, *Lactobacillus**, *Micrococcus*, *Pediococcus*, *Staphylococcus* (*S. aureus* anaerobic), *Vibrio**	*Hansenula*, *Saccharomyces*	
0.88	-	*Candida*, *Debaryomyces*, *Hanseniaspora*, *Torupolis*	*Cladosporium*
0.87	-	*Debaryomyces**	-
0.86	*Micrococcus**, *Staphylococcus* (*S. aureus* aerobic), *Vibrio* (*V. costicolus**)	-	-
0.84	-	-	*Alternaria*, *Aspergillus**, *Paecilomyces*
0.83	*Staphylococcus**	*Debaryomyces**	*Penicillium**

A_w	Bacteria	Yeasts	Moulds
0.81		Saccharomyces*	Penicillium
0.79	-	-	Penicillium*
0.78	-	-	Aspergillus Emericella
0.75	Halobacterium, Halococcus (halophilic bacteria)	-	Aspergillus*, Chrysosporium
0.62	-	Saccharomyces*	Eurotium*
0.61	-	-	Monascus (Xeromyces)

* Some isolates

Leistner *et al*. (1981)

Leistner and Rodel (1975)

Troller (1979)

APPENDIX 2

Fundamentals of the thermodynamic approach to a_w

Since most of the literature published on a_w deals with thermodynamical formulae and concepts, we want to introduce here the pathway between the classical expressions that can be found in common physico-chemistry textbooks and the expressions actually used in a_w studies on foods.

a) Basic expression

The chemical potential (G.N. Lewis) of the solvent in a solution is given by:

$$\mu_1 = \mu_1^o + RT \ln a_1 = \mu_1^o + RT \ln N_1 \cdot \gamma_1 \qquad (I)$$

where:

μ_1 = chemical potential of the solvent

μ_1^o = chemical potential of the solvent at a standard or reference state (the absolute values of the chemical potentials are not known)

R = universal constant gas law

T = absolute temperature of the system (^oK)

N_1 = solvent molar fraction

γ_1 = solvent activity coefficient

a_1 = solvent activity

The chemical potential can also be expressed using the osmotic (rational) coefficient (g), as:

$$\mu_1 = \mu_1^o + g\, RT \ln N_1 \qquad (II)$$

g is called the osmotic (rational) coefficient because it is practically equivalent to the ratio between the actual osmotic pressure, and the ideal (theoretic) osmotic pressure of a given solution.

Expression (II) is still difficult to apply in practice. This is why a new expression was developed:

$$\mu_1 = \mu_1^o - \phi\, RT \frac{M_1}{1000} \cdot \Sigma\, m_i \qquad (III)$$

where:

ϕ = osmotic (practical) coefficient

Σm_i = summation of all molalities of all the ions in the solution. For only one electrolyte, the molecule which produces n ions, will be $\Sigma m_i = \nu \cdot m$

M_i = molality of the solvent

In the case of only one solute (e.g. NaCl), we can write:

$$\mu_1 = \mu_1^o - \phi \, RT \frac{\nu . m . M_1}{1000} \tag{IV}$$

Comparing Equations (I) and (IV) it follows:

$$\boxed{\ln a_1 = - \phi \frac{\nu . m . M_1}{1000}} \tag{V}$$

which relates the solvent activity to the osmotic (practical) coefficient.

The acitivity in a solution is usually given as the ratio between fugacities:

$$a_1 = f_1 / f_1^o \tag{VI}$$

where f_1 is the fugacity of the solution and is the fugacity of the solvent in the state of reference (pure liquid at a pressure of 1 atm and at the same temperature T of the solution).

The fugacity f is a corrected pressure. In ideal systems it is identical to partial pressure of the respective component. It is easy to see that in aqueous systems a_1 will be the water activity; and it will be equal to the ratio of the partial pressures (see Equation [1])

$$a_w = \frac{p_1}{p_1^o} \approx \frac{f_1}{f_1^o} \tag{VII}$$

From (V), (VI) and (VII) it follows that:

$$\boxed{a_w = \exp \left(- \phi \frac{\nu . m . M_1}{1000}\right)} \tag{VIII}$$

for simple solutions (only one solute) or:

$$\boxed{a_w = \exp\left(- \phi M_1 \frac{\sum_{i=1} \nu_i m_i}{1000}\right)} \qquad \text{(IX)}$$

Equation (VIII) or (IX) are the basis of any approach to the theoretical calculation of water activity in food systems.

b) Water activity and osmotic pressure

Water activity is sometimes more easily understood when related to osmotic pressure. As a matter of fact, a direct relationship between osmotic pressure and a_w exists. From classic thermodynamics:

$$\Pi \cdot V = RT \ln (p_1^o/p_1) \qquad \text{(X)}$$

where:

Π = osmotic pressure of the solution

V = partial molar volume of the water in the solution (normally it is taken as the volume of 1 mole of water in solution at temperature T).

From (VII) and (X) it follows that:

$$\boxed{\Pi = \frac{RT}{V} \ln (1/a_w)} \qquad \text{(XI)}$$

Some water activities (a_w) and their corresponding osmotic pressures (OP) which have been related to some biological phenomena are shown in the next table:

RELATIONSHIP BETWEEN WATER ACTIVITY (a_w) AND OSMOTIC PRESSURE (OP) AND SOME BIOLOGICAL PHENOMENA

a_w	OP (*)	Phenomenon
0.989	15	Permanent wilting point of soil
0.890	150	Limit for hydrophilic fungi
0.800	294	Limit for mesophilic fungi
0.700	450	Limit for xerophilic fungi

(*) on atmospheres at 18^{o}C

It can be seen that the osmotic pressure of any aqueous system rises steeply as its water activity falls; consequently, aqueous systems with low water activities and high osmotic pressures are normally incompatible with living microorganisms due to the osmotic effects which tend to dehydrate the microbial cells.

c) The Ross' Equation (II)

The well-known Gibbs-Duhem equation for an open homogeneous system (for example, one phase in a heterogeneous system) is

$$S\,dT - V\,dp + \sum_{i=1}^{m} n_i\, d\mu_i = 0 \qquad \text{(XII)}$$

where n_i is the number of moles of components i.

In isobaric (dp = 0) and isothermal conditions (dT = 0) we can write:

$$\sum_{i=1}^{m} n_i\, d\mu_i = 0 \text{ (P, T constant)} \qquad \text{(XIII)}$$

From Equations (I) and (XIII) it follows that:

$$\sum_i n_i\, d\,(\ln a_i) = 0 \qquad \text{(XIV)}$$

In a binary solution (e.g. NaCl and water), we can write:

$$55.5\, d\,(\ln a_w) = -\, m_i\, d\,(\ln a_i) \qquad \text{(XV)}$$

The number of moles was changed to molality, then

m_i = moles i (solute)/kg of solvent

55.5 = moles of water/kg of solvent

The solute activity (a_i) in this binary mixture is expressed as

$$a_i = m_i \gamma_i^0 \qquad \text{(XVI)}$$

where γ^0 is the solute activity coefficient in the binary system, adapted for molalities. Substitution gives:

$$d\,\ln(a_w) = -\frac{1}{55.5}\, m_i \quad d\,\ln(m_i\gamma_i^0) \qquad \text{(XVII)}$$

In a multi-component solution of water plus n components, Equation (XVII) generalises into

$$d \ln(a_w) = -\frac{1}{55.5} \sum_{i=1}^{n} d \ln(m_i \gamma_i^{'}) \qquad \text{(XVIII)}$$

Here $\gamma^{'}$ is the activity coefficient of the solute component i in the system. As a result of the interaction among the different solute species, in the complex mixture the activity coefficients of the single solutes take another value than that of the one-component solution. These very many interactions, of which detailed knowledge is usually not availble, make Equation (XVIII) very difficult to solve without simplification.

If solutions are not too concentrated, the interaction between different solute components may be assumed to be negligible. Different solute components do not "see" each other, i.e., with respect to each other they behave perfectly or, as Ross (1975) assumed, the interaction effects between those components "cancel on the average", which means mathematically

$$\gamma_i^{'} = \gamma_i^0 \qquad \text{(XIX)}$$

Equations (XVIII) and (XIX) yield

$$d \ln(a_w) = \frac{1}{55.5} [m_1 d \ln(m_1 \gamma_1^0) + m_2 d \ln(m_2 \gamma_2^0) + m_3 d \ln(m_3 \gamma_3^0) + \ldots]$$

Substitution of Equation (XV) and integration yields

$$\ln(a_w) = \ln(a_w)_1 + \ln(a_w)_2 + \ln(a_w)_3 + \cdots$$

which is the equation as derived by Ross (1975):

$$\boxed{a_w = (a_w)_1 (a_w)_2 (a_w)_3 (a_w)_4 \cdots} \qquad \text{(XX)}$$

Thus the water activity of a complex solution becomes simply the product of the water activity values of the aqueous solutions of each component, when measured at the same molality as in the complex solution. Fitting Equation (XX) with real mixtures, Bone et al. (1975) and Ross (1975) showed with different mixtures of sugar, salts and non-soluble food ingredients the error in calculations at $a_w > 0.8$ being smaller than 2% relative.

At high a_w, as long as the mixture remains moist Equation (XX) of Ross gives a reasonable estimate for its a_w. At lower a_w for solid mixtures the equation gives large deviations. An example of this has been described by Chuang and Toledo (1976). For the prediction of a_w of mixtures

in the intermediate moisture range (0.60 to 0.95), it has proved to be a useful tool.

d) Water activity below $0^{o}C$

The relationship between water activity and temperature below freezing can also be determined from thermodynamic considerations. It is possible to arrange Equation (I) in order to calculate the solvent (solid) activity as a function of the solvent (liquid) activity.

$$\mu_s = \mu_1^o + RT \ln a_s \qquad \text{(XXI)}$$

where:

a_s = activity of the solvent (solid)

μ_1^o = chemical potential of the solvent (liquid) in the reference state

μ_s = chemical potential of the solvent (solid)

The Equation (XXI) can be arranged as

$$R \ln a_s = \frac{\mu_s}{T} - \frac{\mu_1^o}{T}$$

taken partial derivatives with regard to temperature

$$R \left(\frac{\partial \ln a_s}{\partial T}\right)_P = \left[\frac{\partial (\mu_s/T)}{\partial T}\right]_{P,N} - \left[\frac{\partial (\mu_1^o/T)}{\partial T}\right]_{P,N}$$

as in general

$$\left[\frac{\partial (\mu_i/T)}{\partial T}\right]_{P,N} = - \frac{\bar{H}_i}{T^2}$$

where H_i is the entalphy of the system; it follows that

$$\left(\frac{\partial \ln a_s}{\partial T}\right)_P = \frac{H_1^o - H_s}{RT^2} = \frac{\Delta H_f}{RT^2} \qquad \text{(XXII)}$$

where ΔH_f is latent heat of fusion of ice (state change from solid to liquid). As the solid has the same reference state as the liquid (convention), the activity of the solvent (liquid) should be the same as the solvent (solid) activity in the freezing point at equilibrium.

$$\frac{d \ln a_1}{dT} = \frac{\Delta H_f}{RT^2} \qquad \text{(XIII)}$$

As $\Delta H = f(T)$, it is possible to apply Kirchoff's equation

$$\left[\frac{\partial (\Delta H)}{\partial T}\right]_P = \Delta Cp$$

or

$$\left[\frac{\partial (\Delta H)}{\partial T}\right]_P = (Cp)_1 - (Cp)_s = \Delta Cp \qquad \text{(XXIV)}$$

where:

$(Cp)_s$ = heat capacity of ice (solid) at constant pressure (P)

$(Cp)_1$ = heat capacity of water (liquid) at constant pressure (P)

In a small temperature range, if the heat capacities can be considered constants, it follows that

$$\int_{\Delta H_f^o}^{\Delta H_f} d\,(\Delta H_f) = \int_{T_o}^{T} \Delta Cp.dT = \Delta Cp\,(T - T_o)$$

or

$$\Delta H_f = \Delta H_f^o + \Delta Cp\,(T - T_o)$$

The difference $(T_0 - T)$ is usually known as the cryoscopic descent of the solution (θ); taken also $L_0 = \Delta H_f^o$ for the short we can write

$$\Delta H_f = L_o - \theta\,.\,\Delta Cp \qquad \text{(XXV)}$$

From Equations (XXIII) and (XXV) it follows that

$$d \ln a_1 = \frac{L_o - \theta\,.\,\Delta Cp}{RT^2}\,.\,dT$$

As $T = T_o - \theta$ ∴ $dT = - d\theta$; it follows that

$$- d \ln a_1 = \frac{L_o - \theta . \Delta Cp}{R (T_o - \theta)^2} \qquad (XXVI)$$

In order to simplify the integration, denominator of (XXVI) can be developed in serials:

$$\frac{1}{(T_o - \theta)^2} = \frac{1}{T_o^2} (1 - \frac{\theta}{T_o})^{-2} = \frac{1}{T_o^2} (1 + \frac{2\theta}{T_o} + \frac{3\theta^2}{T_o^2} + \ldots)$$

it follows that

$$- d \ln a_1 = \frac{1}{RT_o^2} (1 + \frac{2\theta}{T_o} + \frac{3\theta^2}{T_o^2} + \ldots) (L_o - \theta . \Delta Cp) \, d\theta$$

or

$$- d \ln a_1 = \frac{1}{RT_o^2} [L_o + (\frac{2L_o}{T_o} - \Delta Cp)\theta + \ldots] \, d\theta \qquad (XXVII)$$

Finally we integrate (XXVII), introducing the state of reference as the lower limit of integration in the integral of

$$- \int_{\ln a_1^o}^{\ln a_1} d (\ln a_1) = \frac{L_o}{RT_o^2} \int_0^\theta d\theta + \frac{1}{RT_o^2} (\frac{2L_o}{T_o} - \Delta Cp) \int_0^\theta \theta . d\theta + \ldots$$

it follows that:

$$- \ln a_1 = \frac{L_o . \theta}{RT_o^2} + \frac{\theta^2}{RT_o^2} (\frac{L_o}{T_o} - \frac{\Delta Cp}{2}) + \ldots$$

as $a_1 = a_w$, it follows that:

$$a_w = \exp\left\{-\frac{L_o}{RT_o^2}\left[\theta + \theta^2\left(\frac{1}{T_o} - \frac{\Delta Cp}{L_o^2}\right) + \ldots\right]\right\} \qquad \text{(XXIII)}$$

Usually it is enough for calculations to take only the terms shown in Equation (XXIII). In the case of water we have:

L_o = 1438 cal mol^{-1} (molar heat of ice fusion 0°C and 1 atm)

$(Cp)_l$ = 18 cal mol^{-1} grado^{-1}

$(Cp)_s$ = 9 cal mol^{-1} grado^{-1}

T_o = 273,16 °K

replacing this values in Equation (XXIII) we have finally

$$\boxed{a_w = \exp\left[-9.702 \cdot 10^{-3} \cdot \theta - 5.2 \cdot 10^{-6} \cdot \theta^2\right]} \qquad \text{(XXIV)}$$

This equation apply when water crystallises as pure ice.

METHODS OF FISH SALTING

by

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1. Introduction

Salting is one of the oldest techniques for preserving fish, and it is a traditional processing method used world wide. It is also a simple method of fish preservation with salt and fish, and sometimes water, added as the only ingredients. Often, salting is used in combination with drying and smoking. However, if the salting process is carried out incorrectly, due mainly to the use of poor quality starting materials, that is stale fish, or by the addition of insufficient salt, the product can spoil and is lost. In fact thousands of tonnes of poorly processed and stored salted fish are lost every year.

2. The action of salt

The most important effect of salt is the removal of water from the flesh to the point where microbial and enzymatic activities are retarded. This process of dehydration is due to the different concentration between the weak salt solution inside the flesh, and the high salt concentration outside the flesh of the fish. As water is withdrawn from the fish due to an osmotic gradient, salt penetrates the tissues, i.e. when the water goes out, salt goes in. During brining, this process of water/salt movement continues until the strength of the salt solution inside and outside the fish flesh is equal.

Other commonly accepted minor mechanisms for the action of salt as a preservative (Lupin, 1982a) include:

1. The combined action of sodium cation (Na^+) through protoplasmic anions of the microbial cells and this has a toxic effect on microbes.

2. Sodium chloride alters the enzymatic system of microbial cells particularly proteolytic enzymes, either lowering the activity or inhibiting the activity of these enzymes.

3. In brines, the oxygen concentration is much lower and this will affect, in particular, aerobic bacteria and reduce lipid oxidation.

4. Salt synergizes the action of carbon dioxide and low pH, which microbes are quite sensitive to.

3. Salt quality

Pure common salt is sodium chloride, but commercial salt contains a number of impurities. The type of impurities depends on the source and the method of manufacture of the salt. There are three main sources of salt:

1. Solar salt which is made by evaporation of seawater or salt-lake waters by the action of the sun and wind. This is the common method of salt manufacture in the Philippines.

2. Brine evaporated salts are obtained from underground salt sources. The salt deposit is brought to the surface in solution and this solution is heated to evaporate the water.

3. The purest natural salt are the rock salts. These do not need any further treatment for purification.

3.1 Chemical composition

Commercial salts vary widely in their composition, the best quality can have as high a sodium chloride content as 99.9%. This would be too expensive for use on fish. At the other end of the scale, the sodium chloride content of poor quality salt can be as low as 80%. Apart from contamination such as dust, sand, mud and moisture, the main chemical impurities of commercial salt are calcium, magnesium chloride and sulphate, sodium sulphate, carbonate and traces of copper and iron (TDRI, 1982).

Solar salt is less pure than the mine evaporated salt. This is because many of the salts that are present in seawater will be included following evaporation. Salt intended for use on fish should have a low content of magnesium and calcium. Magnesium salt imparts a bitter taste and some toughness to the fish flesh. Calcium salts give the flesh of fish a heavy toughness, and this is retained even after desalting the fish prior to cooking. If this fish is sun dried, it becomes brittle. However, a low calcium level has an advantage. A certain degree of stiffness and a white appearance is evident at calcium concentration of about 0.5%. In contrast when pure sodium chloride is used the flesh is soft, and will have a yellowish colour (Lupin, 1982b).

Magnesium chloride is hygroscopic. Salt containing magnesium chloride will encourage uptake of moisture from the air and this will affect the keeping quality of salted and salted-dried fish. Copper present in trace quantities may lead to a brown discolouration of the surface of the fish and this may be visually unacceptable. Traces of copper and iron encourages rancidity, i.e. they act as catalyst for the oxidation of fats (Lupin, 1982a).

3.2 Microbiological purity

Salt tolerant bacteria are often found in many commercial salt samples. These are the so called halophiles or salt loving bacteria. These microorganisms require saline conditions for growth and survival. One group of halophiles can easily be identified in salt because of their pink or red colouration. "Pinking" can be seen on infected salted fish samples. The red halophilic bacteria are putrefactive and produce unpleasant odours, particularly on moist salted fish. This is not as much of a problem on dried-salted fish.

There are also halophilic moulds that can grow on dried-salted fish. They form dark patches on the surface which are called "dun".

3.3 Physical properties of salt

Salt comes in many grain sizes. Fine salt grains dissolve more rapidly in water, so it is much easier to make a brine from fine grade salt. If however, the same fine salt grains are used directly on fish, a condition called "salt burn" can develop. This is a condition where the moisture on the surface of the fish is removed too rapidly, and a hard crust forms which acts as a barrier to further removal of moisture. Conversely, if we use large salt crystals directly on fish, the action of the salt in removing moisture from the flesh may be too slow and this may allow for bacterial spoilage to occur. In effect, the salting process is a race between the removal of moisture and the action of bacteria in spoiling the fish. The ideal salt mixture for salting fish directly is a mixture of fine grain and coarse grain salt, normally in a ratio of 2/3 coarse grain and 1/3 fine grain salt (TDRI, 1982: Lupin, 1982a).

4. Raw material quality

Fresh fish must be used to produce the best quality products. Stale or spoiled fish can not be improved by any form of processing, and that includes salting, and the phrase "rubbish-in, rubbish-out" holds true.

The rate of salt uptake and water removal in fish flesh is more difficult under the following conditions:

1. Thick pieces of fish are more difficult to salt because the moisture must be removed from the center of fish flesh. Splitting, gutting, cutting fish into pieces is necessary for large fish to facilitate efficient water removal and salt uptake.

2. Fatty fish are more difficult to salt compared to lean fish due to barriers caused by the various fat layers in the flesh. The fattier the fish the slower the removal of moisture and salt penetration.

3. Unscaled fish, particularly fish where the scales are firmly attached, will have slower salt penetration and water removal. On fish where the scales are fairly loose problems will be minimal.

4. It is more difficult to salt very fresh fish where the flesh is still firm while the flesh of stale fish will be softer, therefore showing less resistance to water loss and salt penetration.

5. Salt penetration and water removal is quicker at higher temperatures, but the rate of bacterial spoilage is also quicker.

The amount of salt present in the flesh of the fish, influences the requirements of water removal for subsequent processing such as drying and smoke-drying techniques.

1. The higher the salt concentration in the flesh the greater the amount of water that has been removed during salting, and consequently the less water that remains to be removed during any drying process that follows.

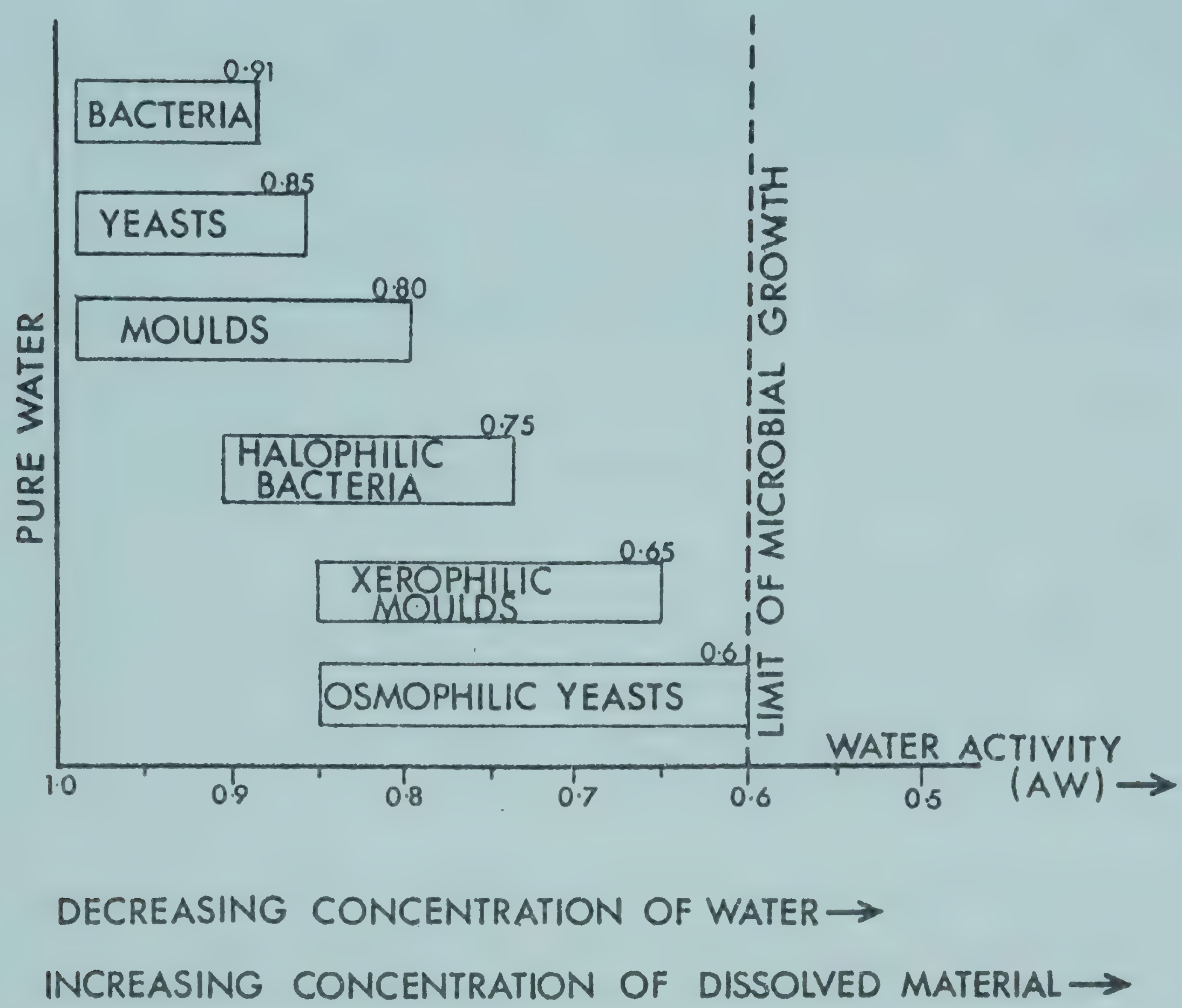
2. The presence of salt in the fish flesh actually slows down the drying process. The higher the salt concentration, the slower will be the drying i.e., salt acts to retain water in the flesh.

3. Salt encourages the absorbtion of moisture from the air particularly at high ambient relative humidities (>75%).

5. Influence of salt on water activity (A_w)

The water activity of foodstuffs is a measure of the water available in food materials that can support microbial growth. The lower the A_w the more microbially stable the product is. The A_w is a more accurate measure of the preserved "status" of a food compared to measuring the moisture content. In fact the moisture content figure is likely to be misleading as it takes no account of tightly "bound" water of foods and the binding influence of salts and organic materials on the remaining water. Removing water from foods reduces the A_w, but adding salt (and other material such as sugars and glycol) will also reduce the A_w. The limits of growth for specific groups of microorganisms with respect to water acitivity is shown in Figure 1.

Figure 1 Growth ranges of microorganisms with respect to water activity



Parry and Pawsey, 1973

The A_w for a saturated salt solution is 0.75. Fish flesh in equilibrium with a saturated salt brine will also register an A_w of 0.75. A lower A_w is not possible through the action of salt alone. From Figure 1, all microorganisms with their growth ranges above 0.75 will not be viable. Only some of the xerophilic moulds and osmophilic yeasts can grow. To eliminate the possible problem of the latter two groups, the A_w will have to be lowered to beyond 0.65 and 0.6 (limit of all microbial growth) respectively. Pressing the salted fish will lower the A_w marginally below 0.75, but drying or smoke-drying can significantly lower the A_w (Lupin, 1982a).

Problems with spoilage may be experienced when storing salted products at high ambient relative humidity. The relationship between equilibrium relative humidity (ERH) and A_w can be expressed as follows:

$$\% \text{ ERH} = A_w \times 100$$

For salted products with an Aw of 0.75, if the equilibrium relative humidity is greater than 75%, the salted product will take up moisture from the atmosphere, increasing the A_w and consequently introducing the possibility of spoilage by other groups of microorganisms. The use of moisture barrier packaging under such circumstances is advisable.

6. Salting methods

There are two forms of salting, wet salting and dry salting.

6.1 Wet salting

Brining and pickling are the two methods commonly used for wet salting. The method used largely depends on whether the product will be further processed by drying or smoking, or preserved by salting alone.

6.1.1 Brining

Fish are usually brined prior to drying and smoking, and brining is used when a light to heavy salt content is desired. Brines are normally used at strengths of about 80 to 100%. This is equivalent to 270 to 360 g of salt/litre. It is then the length of time a particular species of fish remain in the brine that will determine the final salt content.

When the fish are placed in a brine, the salt removes water from the fish which means the brine becomes diluted. Thus a saturated brine will not remain saturated unless salt is added and the brine (and fish) are stirred. In practice sufficient undissolved salt is allowed to remain in the bottom of the container to keep the brine up to strength. Stirring also mixes the pockets of diluted brine that form immediately around and between fish.

6.1.2 Pickle curing

Pickle curing starts as a dry salting method. Prepared fish are layered alternately with dry salt in a water tight container (food grade can or plastic) using a fish to salt ratio of 1 to 0.3 - 0.4. A pickle will quickly start to form with the surrounding salt dissolving in the water extracted from the fish. The pickle is retained inside the container and will eventually cover all the fish. However, the fish must be covered with liquid as rapidly as possible to reduce any problems of oxidation. To speed up the process saturated brine can be added, and the fish kept immersed, with a wooden cover and weights, until salting is completed.

Pickle curing is more suitable for oily fish, i.e. fish with an oil content in excess of 2%. During the period fish are immersed in the pickle, oxidation of the fat is minimised.

6.2 Dry salting or kench curing

As with the pickle cure, kench curing involves placing prepared fish and salt in alternate layers. However, the liquid pickle that forms is allowed to drain. Large stacks of layered fish and salt can be built, often reaching 1 to 2 m in height. A cover with a weight is placed on top of the stack to press the fish. This encourages faster salt penetration and water removal.

The fish should be restacked every 24 h, so that the fish previously on top of the stack end up at the bottom of the new stack, with more salt added when necessary.

Because much of the fish are exposed to the atmosphere this method should only be used for lean fish. Problems may also be encountered under tropical condition where the fish are more susceptible to spoilage and insect attack. Restacking regularly should minimise these problems.

7. Salting time

Typical salting time for fish to reach salt saturation are (Lupin, 1982a)

Small pelagic (headed and gutted)	36 - 40 h by pickling
Intermediate size splitted fish	50 - 60 h by kench cure
Shark flesh (2 cm thick)	60 - 70 h by kench cure

After these periods the pressing of fish is advisable in order to reduce the brine content inside the flesh to improve keeping quality.

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DRIED FISH PRODUCTS OF TAWI-TAWI AND SULU

by

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Introduction

In the Philippines, 46% of the total fish catch is dried (FAO, 1982). In the Sulu Archipelago, drying is the most suitable method of fish processing, as the area, especially Tawi-Tawi, receives little rainfall. Water supply is scarce and rainwater is the main source of drinking. Well water is sold at approximately ₱2 to 6 per 5 L, depending on the duration of the dry season. Other fish preservation methods like freezing and canning cannot be easily adapted because of high capital costs and are too expensive for the local people. Smoking is not very popular, however, fish are broiled over an open fire and products have a shelf-life of almost one day at ambient temperature.

The cuisine of the Badjaos, Sama and Tausog tribes in Tawi-Tawi and Sulu offers a rich variety of traditional foods. Dried as well as non-dried fish products are readily available in local markets. Some products are limited to local consumption; others are transported to Manila and Cebu where they may be exported. Philippine export of fish and fishery products are shown in Table 1.

The vast majority of dried fish products in Tawi-Tawi and Sulu are produced on a small-scale backyard industry. Problems encountered at this level of production include those related to handling, hygiene, quality, distribution, storage and marketing. Most of the producers still adhere to the traditional methods of production and involve methods which are usually labor intensive and lacking in quality assurance. In most areas, hygiene and sanitation are the greatest problem as the fish are exposed to dust, dirt from the floor of the processing areas and from the unwashed hands of the processors. To overcome problems of spoilage or short shelf-life of the products, excessive amounts of salt are usually added. Other preservatives are readily used.

Most traditionally processed seafoods are not well packed but are carelessly stocked in cartons or jute sacks. Few are packed in cellophane bags. These problems are compounded by the general lack of education regarding good handling and processing methods, and processors are resistant to change and modernization. As they are small family establishments, most industries have limited capital and are not aware of the types of assistance available from the

Table 1 Export of dried fish/fishery products (kg)

Item	1981	1982
Fish	131,334	259,969
Abalone	10,734	14,966
Sharkfins	41,478	8,021
Sea cucumber	613,777	480,849
Seaweeds	14,936,863	15,119,472

(BFAR, 1982)

various government agencies and financial establishments. All these factors limit the development of the traditional fishery industries in the areas.

Drying as a method of fish preservation remains popular to this day because of certain advantages. The techniques are usually simple and do not require high technology or expensive equipment.

A higher quantity of marine fish are landed in Tawi-Tawi by commercial fishing vessels than in Sulu (Table 2). The natives prefer fresh fish which are in abundant supply and are much cheaper than dried fish. During bad weather, fish are scarce and people rely on dried fish.

Traditional dried fish products commonly found in the markets of Jolo, Sulu and Bongao, Tawi-Tawi are shown in Table 3. These include "tahay" (splitted-dried whole fish), "tahay manangkay" (dried clam), "tahay tambaya-ngan (dried blood archshell), "sik kaytan" (dried sharkfin), "tahay lappas" (dried abalone), "agal-agal tahay" (dried seaweed), "tahay kahanga" (dried spider conch), "bat tahay" (dried sea cucumber), "tahay kiyampaw" (dried stingray), "tahay sikad-sikad" (resembles whelk conch) but smaller, about 10 cm in length.

The methods of production used are shown in Figures 1 to 6. Other dried fishery products like dried squid are also available in the local markets. The procedures for drying are similar to that of dried fish.

Table 2 Quantity of marine fish landed by commercial fishing vessels by province (metric tons)

	1978	1979	1980	1981	1982
Bongao, Tawi-Tawi	3,825	2,452	2,205	2,016	174
Sulu	-	21	238	384	210
Zamboanga City	37,799	36,082	32,474	42,678	55,991

(BFAR, 1982)

Table 3 Dried fish products of Tawi-Tawi and Sulu

Dried fish products	Local	National
Tahay (fish)*	+	+
Tahay manangkay (Clam, *Tridacna* sp.)	+	-
Sik kaytan[a] (Sharkfins)	-	+
Tahay tambayangan[b] (Blood archshell, *Arca granosa*)	+	-
Tahay lappas (Abalone, *Haliotis asinina* Linnaeus)	-	+
Agal-agal tahay (Seaweeds, *Eucheuma* sp.)	-	+
Tahay kahanga (Spider conch, *Lambis lambis* Linnaeus)	+	-
Bat tahay (Sea cucumber, *Holothuria* sp.)	+	+
Tahay kiyampaw[c] (Stingray, *Dasyatus kuhlii*)	+	-
Tahay sikad-sikad[d]	+	
Tahay tabullae[e] (Squid, *Loligo* sp.)	+	+

* almost all marine fishes are dried

a shark meat dried for local consumption

b method involved is the same with dried clam

c beheaded first and then dried

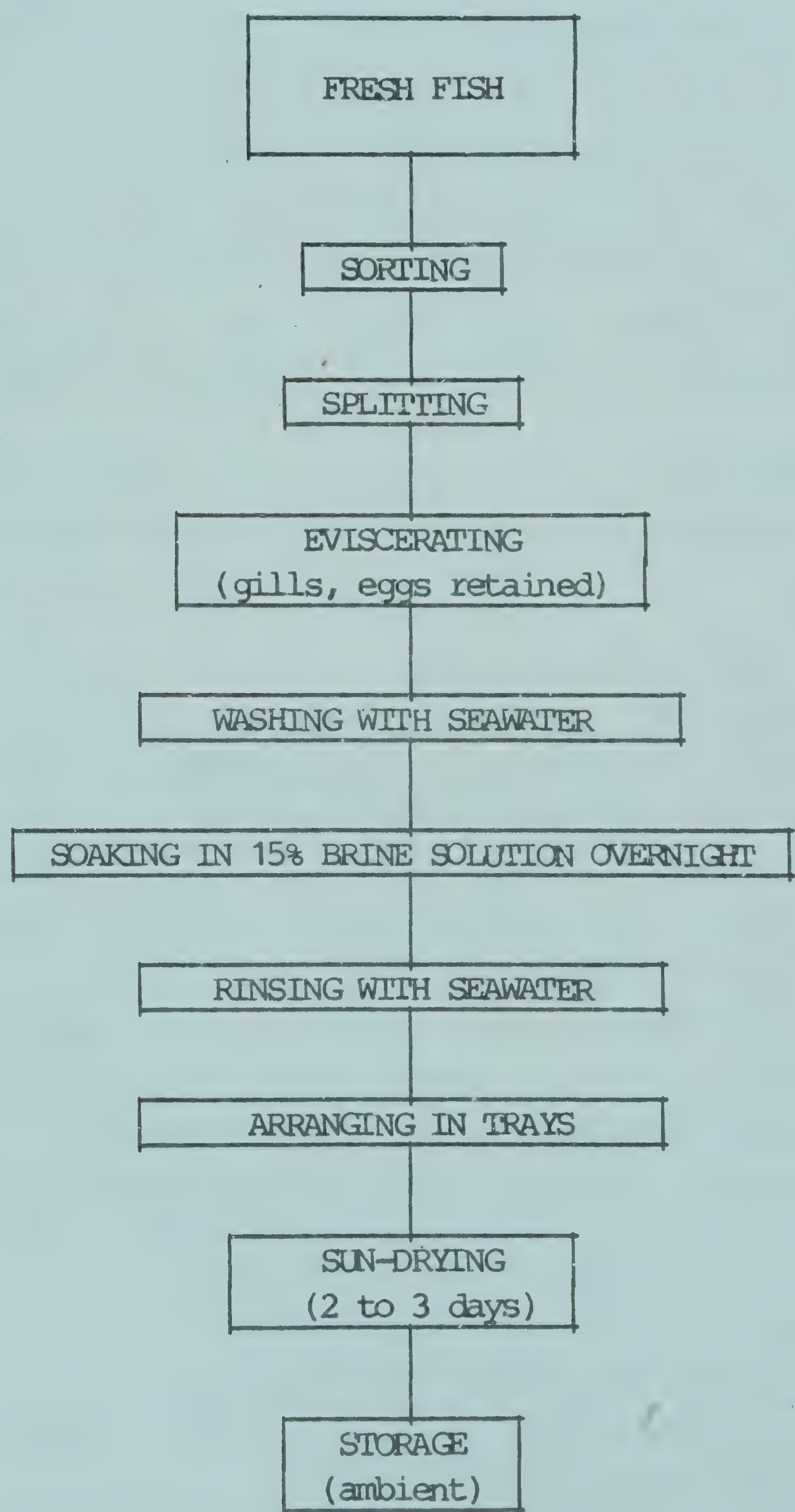
d method of drying is similar to spider conch

e dried directly after washing without removing the entrails

"Tahay" (dried fish)

Of the several types of dried fish products in Tawi-Tawi and Sulu, the most well known is "tahay". This is either split-salted dried or whole dried depending on size. The color varies from very light yellow to light brown. No figures for its annual production are available so that it can be assumed that like all other dried fish products in these areas, "tahay" is produced on a village industry scale only. First class "tahay" is usually made from big fishes of the family Serranidae (groupers, seabasses), Siganidae (rabbitfishes), and Caranx sp. (Figure 1).

Figure 1 Procedure for drying "tahay" (dried fish) in Tawi-Tawi

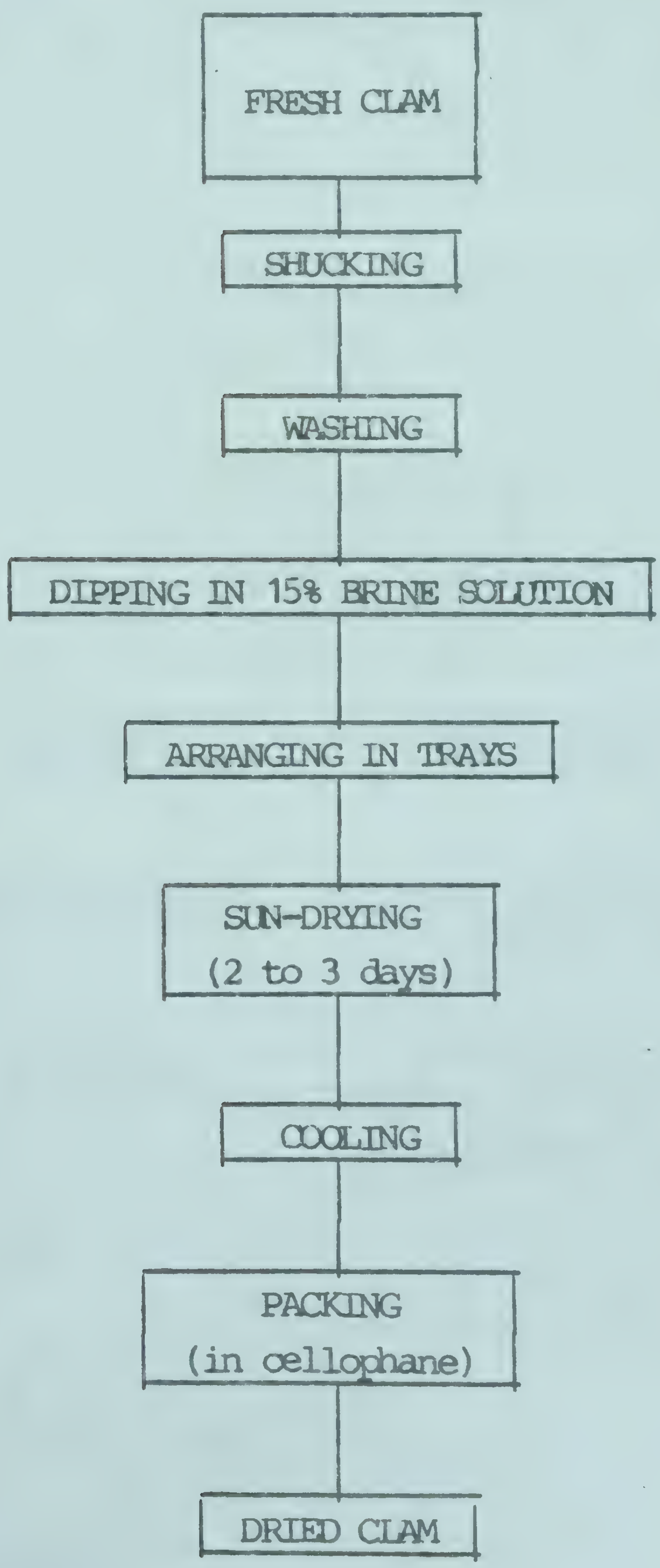


"Manangkay tahay" (dried clam)

The giant clam (*Tridacna gigas*) measures over 1 m across and weigh several hundred kilos. A measurement of 40 to 50 cm is more ommon. The colour of the shell is black and white. The body within the shell display many colours to include white, yellow, purple and blackish red. A smaller giant clam is *Tridacna elongata* (Samarck) which has a dark brown shell. These great bivalves live in waters from 1 to 20 m deep, preferably very salty and are often found in the vicinity of the islands or other rocky areas in Sitangkai. Both the meat and the adductor muscle of the clam is good to eat when prepared raw with lemon and a little salt and pepper (kinilaw).

For the clam to command a better price, processors usually preserve them through sun-drying as shown in Figure 2.

Figure 2 Procedure for drying clam (*Tridacna* sp.)
and Arcshell (*Arca granosa*)



"Tahay tambayangan" (dried arcshell or blood clam)

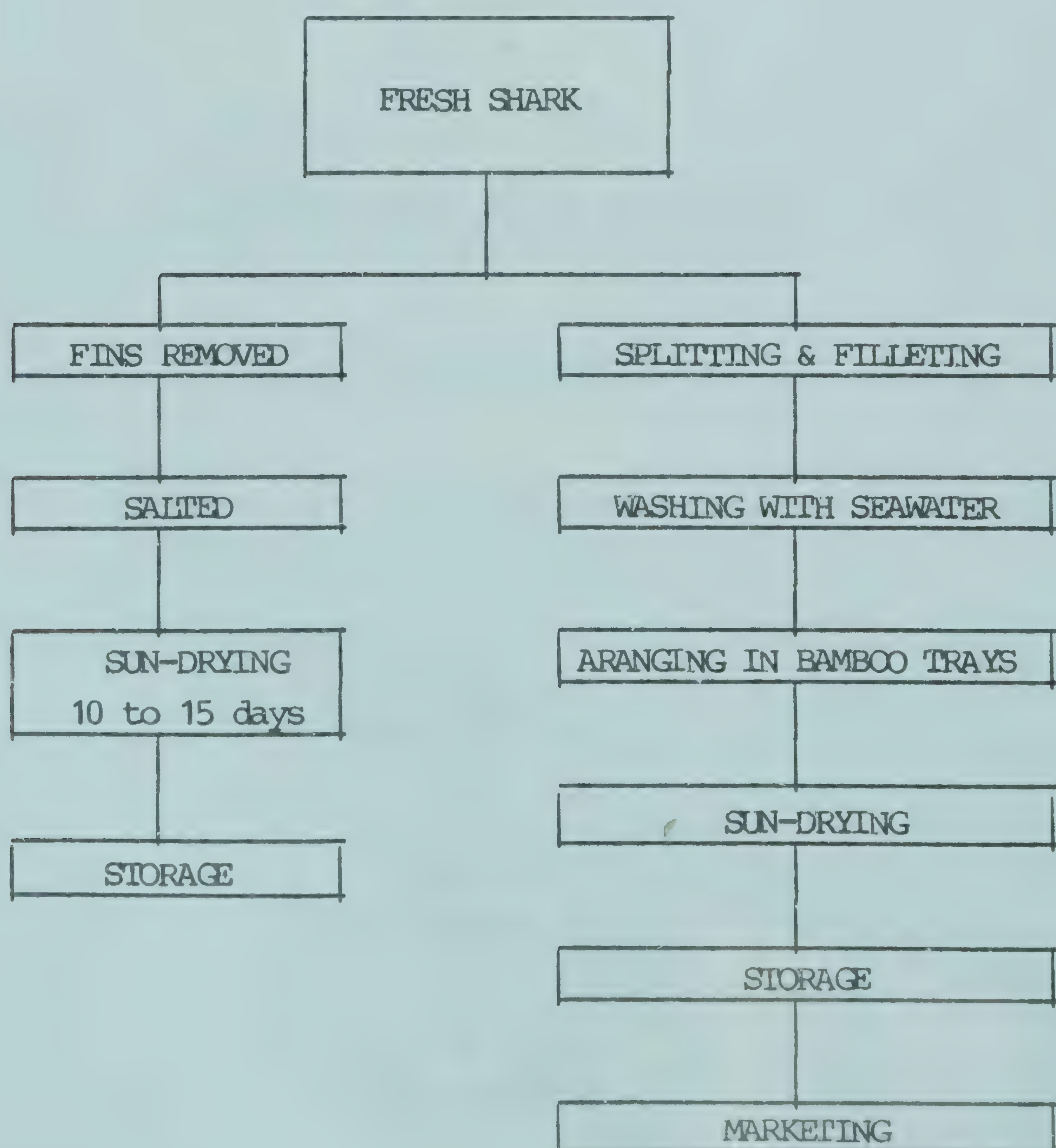
The species *Anadara granosa* or *Arca granosa* comes from the family *Arcidae*. The general color of the shell is brownish black, but whitish near the hinge and there are little white projections along the ridge lines. They are called blood clams since they exude a red brown juice which look like blood. The meat is red-colored. This is of great commercial importance in Malaysia and Indonesia (Davidson, 1976). The Chinese consider it as an appetiser and an aphrodisiac. In Tawi-Tawi and Sulu areas, "tambayangan" meat is incorporated in "ginatan" and "bihon or pancit guisado".

This material is found either in the market of Bongao or Sitangkai, Tawi-Tawi or Jolo, Sulu. The method of drying is shown in Figure 2.

"Sik kaytan" (dried sharkfin)

"Sik kaytan" or sharkfin is the main source of Selachin. Selachin soup is a Chinese delicacy resembling sotanghon soup. Sharks of the families *Carcharinidae* and *Sphyrinidae* are usually caught off the waters of Sulu or Sitangkai, Tawi-Tawi for processing. It is sold at ₱ 200/kilo. The method of production is shown in Figure 3.

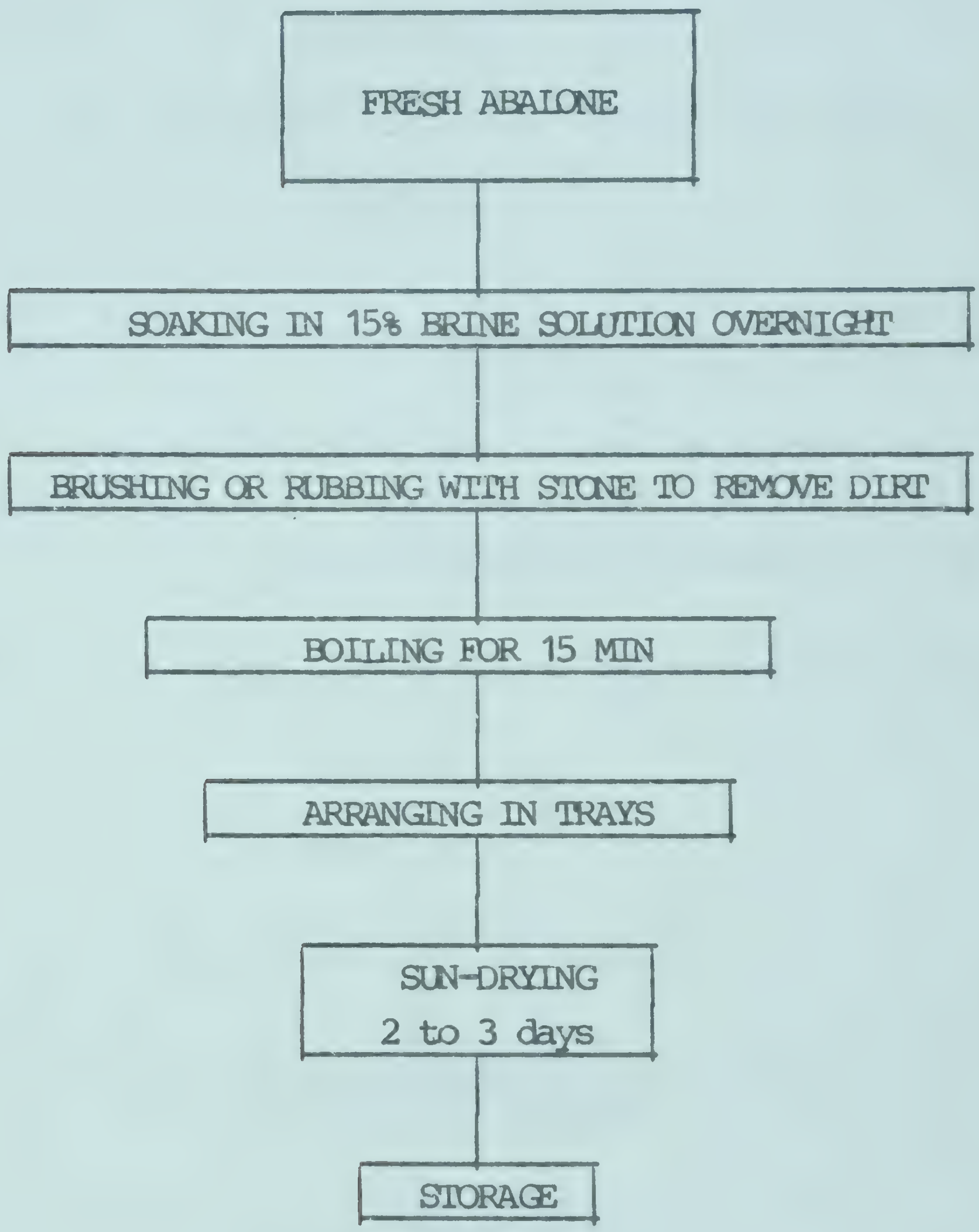
Figure 3 Procedure for drying sharkfins and meat



"Lappas tahay" (dried abalone, *Haliotis asinina* Linnaeus)

"Lappas tahay" is sold in the markets or Chinese stores in Sitangkai. These command better price and are usually transported to Zamboanga and Manila. The method of drying is shown in Figure 4.

Figure 4 Procedure for drying of abalone (*Haliotis asinina* Linnaeus)



"Agal-agal tahay" (dried seaweed, *Eucheuma cottonii* and *Eucheuma espinossum*)

The supply of "agal-agal tahay" is very abundant in both Sitangkai and Bongao, Tawi-tawi. This material is of commercial importance especially when transported to either Cebu or Manila. The method of drying is shown in Figure 5.

Figure 5 Procedure for drying agal-agal (*Eucheuma cottonii* and *Eucheuma espinossum*)

FRESH AGAL-AGAL

SPREADING IN UNIFORM THICKNESS

SUN-DRYING
4 to 5 days

STORAGE

"Tahay kahanga" (*Lambis lambis* Linnaeus)

This fish product as well as that of "sikad-sikad" are processed in the manner shown in Figure 6. These materials are consumed locally but of less commercial importance despite its delicious taste.

Figure 6 Procedure for drying conch (*Lambis lambis* Linnaeus)

FRESH CONCH

ROASTING

REMOVING THE MEAT

CLEANING DIRT BY WASHING

ARRANGING IN TRAYS

SUN-DRYING

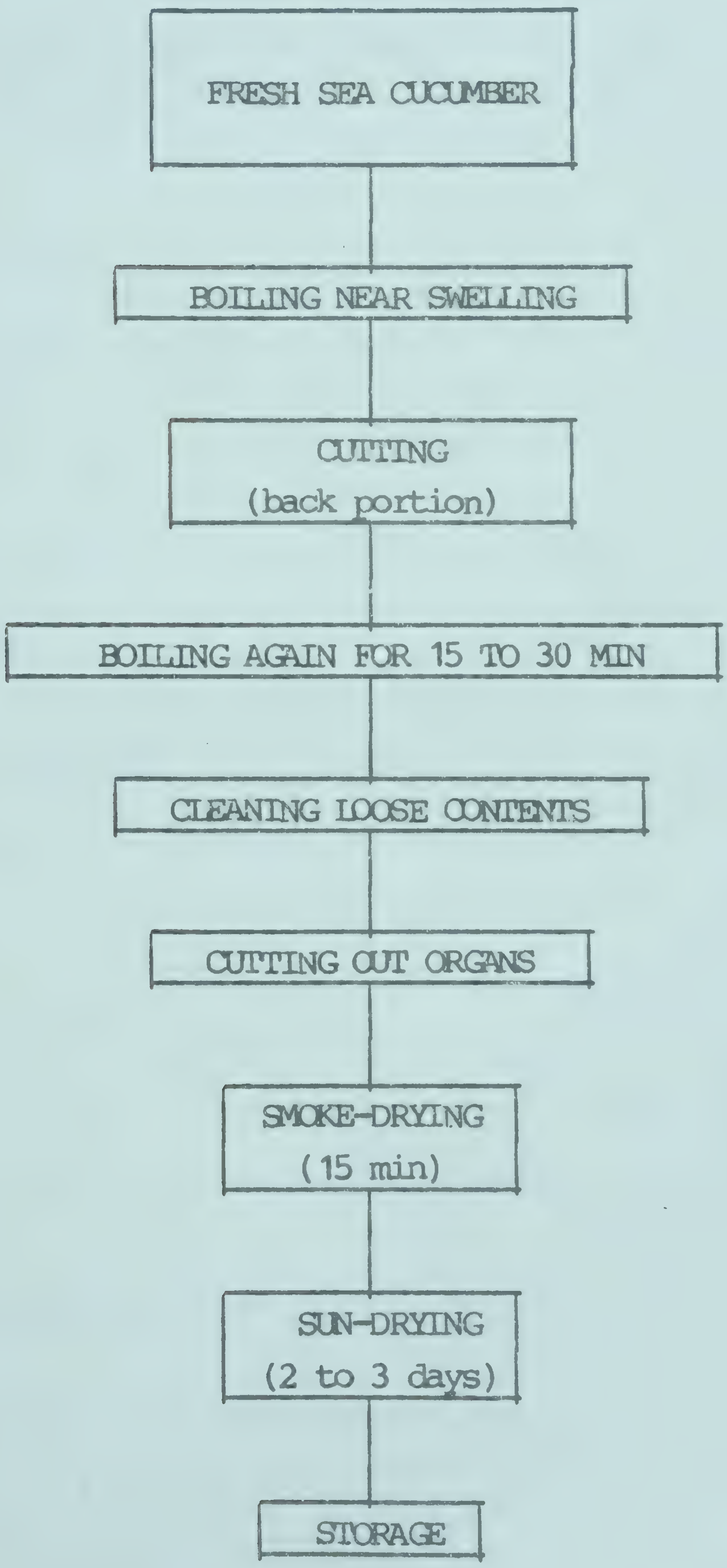
STORAGE

"Bat tahay" (dried sea cucumber, Holothuria sp.)

The so-called "bat duruan" is of commercial importance and commands a better price of about ₱ 150/kilo in Bongao market. Other species of sea cucumber are priced at about ₱ 30/kilo.

Sea cucumber are seasonal. They are found mostly in the shallow waters and seabeds of the sandy Sitangkai and Sangay Siapo and the nearby islands in Tawi-tawi. The method of production is shown in Figure 7.

Figure 7 Procedure for drying sea cucumber (Holothuria sp.)



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PROCESSING AND MARKETING OF CURED FISH IN PERU

by

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Introduction

Fishing is an important economic activity in Peru, which is one of the largest fishing nations in the world. The main species was the anchovy (*Engraulis ringens*) which was processed into fishmeal and oil. Later, this species was substituted by sardine (*Sardinops sagax*). The major capture and landings were in Chimbote, the first fishery port in Peru, using large ships (capacity of 180 to 480 t) and small boats for direct human consumption.

Nevertheless, the consumption of fresh fish is very low, about 10 to 11 kg per capita yearly, compared with the amount of fish landed. Fish is mainly consumed fresh (230,000 t in 1984) and to a limited degree as cured products (approximately 9,800 t in 1984), although the consumption of cured products have been increasing over the past five years (Table 1). Also part of the production of cured fish was exported to Ecuador, Colombia and Brazil in 1984. Similar to local consumption, exports have increased a little in the past few years.

Table 1 Fish consumption (tonnes) in Peru 1980 to 1984

Type of product	1980	1981	1982	1983	1984
Fresh fish	155,748	147,294	150,793	106,722	230,000
Cured fish	5,752	5,571	7,543	5,565	9,758

Processing of cured products

The processing of cured products in Peru is mainly carried out by artisanal methods, with the probable exception of drying. Salted fish is processed

on a semi-industrial scale. The most important cured products processed in Peru are:

- salted fish or "Salpreso",
- dry-salted fish and
- dried fish

Salted fish (Salpreso)

This is the most important cured product which is processed in Peru, with respect to the amount processed and local consumption.

Fish to be salted are captured in small boats (6 to 8 t capacity) and once landed sold and processed as follows:

GUTTING	The internal organs are removed.
WASHING	After gutting, fish are washed in seawater.
SALTING	Salting in a wet stack. Common salt is added (35% with reference to fish weight). Sometimes fish are salted in the market.
STACKING	Stored in wooden troughs.
MARKETING	Two days later salted fish is sold in the local market by "ambulantes" and distributed in other areas.

Salted fish is processed by fishermen and their families; the processing technology is transferred from father to son, and also provides employment for local development.

Marketing

Salted fish is mainly consumed in areas close to the processing centers although it is sold in northern Peru and there is a small export market in Ecuador.

The consumption of salted fish increases during Easter. The main disadvantage of this product is rapid lipid oxidation and the poor sanitary conditions during its domestic processing.

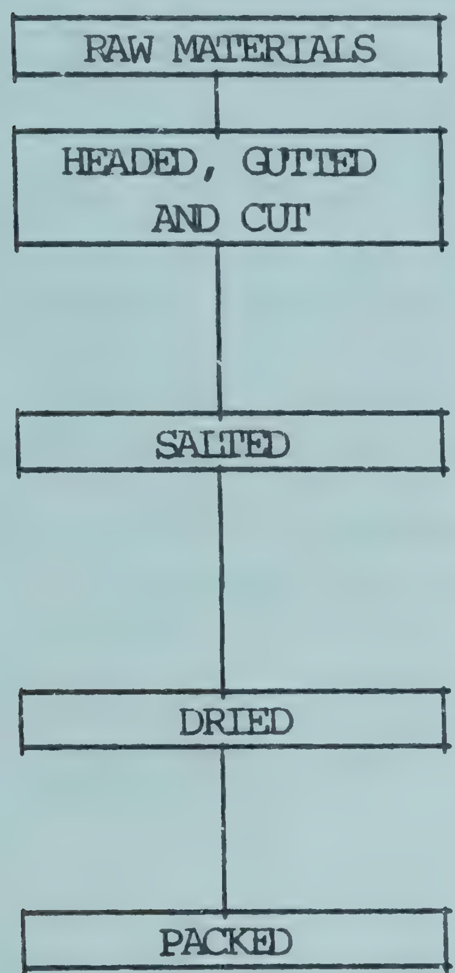
Dry-salted fish

These products are manufactured using white fish such as hake, sharks and rays by artisans even though there are plants for semi-industrial processing.

The processing of dry-salted fish is as follows:

RAW MATERIAL	Fish are headed and gutted on-board.
FILLETING	Fillets of approximately 1.5 cm thick, 25 cm long and 10 cm wide are cut.
SALTING	Salt is added: 30% with reference to fish weight. Wet stack, sometimes pickle cured.
STACKING	Fish are piled with alternating layers of salt up to 1.2 m high.
DRYING (in the shade)	Length of drying depends on the weather: sun and relative humidity. It lasts 4 to 6 days, alternating drying in the shade and in the sun; to avoid over drying of the fish surface.
DRYING	
CONTROL	Approximately 28% humidity.
FISH TRIMMING	Fish are trimmed with a guillotine
PACKING	Fish are packed in cloth sacks.

The processing used for hake (<u>Merluccius gayi</u>) is similar to the aforementioned process, the main difference being the specific characteristics of the species. The process is as follows:



Hake

Once headed and gutted, fish are cut along the dorsal side (butterfly fillet), and two thirds of the vertebral column removed.

Fish are salted adding 30% of salt in alternating layers with fish, and dried for 5 to 6 days, alternating drying in the shade and in the sun.

Fish are packed in jute sacks or polyethylene bags and then put in wooden boxes.

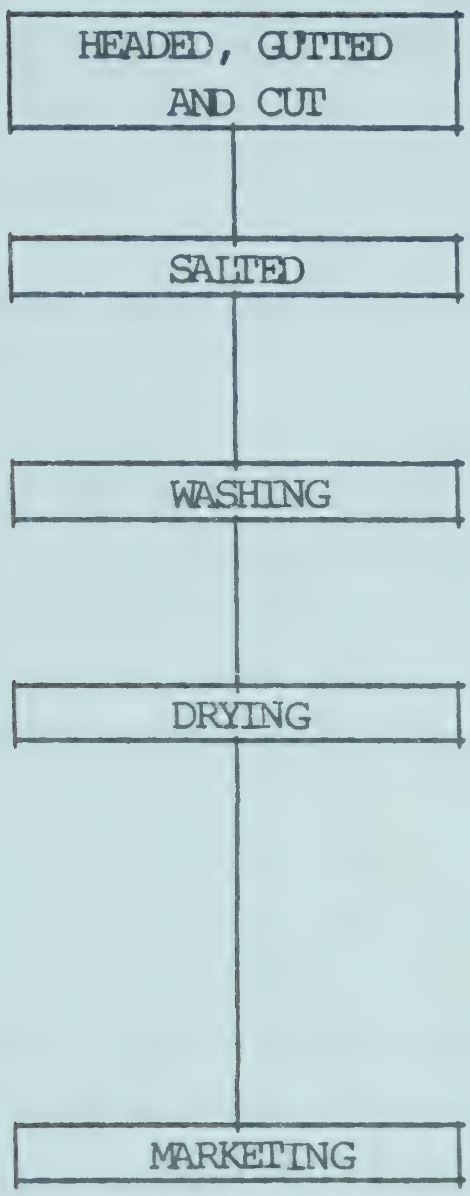
Marketing

These dry salted products are made for the export markets. In 1984, approximately 7,000 t of cured products were exported, a considerable percentage corresponding to dry-salted products. Local consumption is very limited, being significant only during Easter, which is traditional.

Dried fish

The production of these products is very limited and confined to specific areas along the northern coast of Peru, such as the bays of Santa Rosa, San Jose and Pimentel. Occasionally shellfish are also processed in the central coast. Some freshwater species are dried for local consumption, especially in the jungle rivers and the Titicaca lake (the highest in the world located at 4,000 m above sea level). Some of the most important dried products are as follows:

Dried-ray: White fish found in the warm waters of northern Peru, belongs to the Dasyatidae family, mainly species of Rhinobatus.



Fish are first headed, gutted and cleaned on shore; also longitudinal cuts are made on both sides.

Approximately, 30 to 35% of salt is added and the fish are pickle cured on wooden troughs.

After 2 or 3 days of salting, fish are washed with the pickle formed during salting.

Fish are sun-dried in spread places and when the fish acquires certain consistency (about 1 day), a wooden frame is placed in the inner part of the fish 1 longitudinal and two transversal stick. Fish continue to dry for 4 to 5 days, until the product has 30 to 32% moisture content.

The finished product is piled and tied and sent to the market.

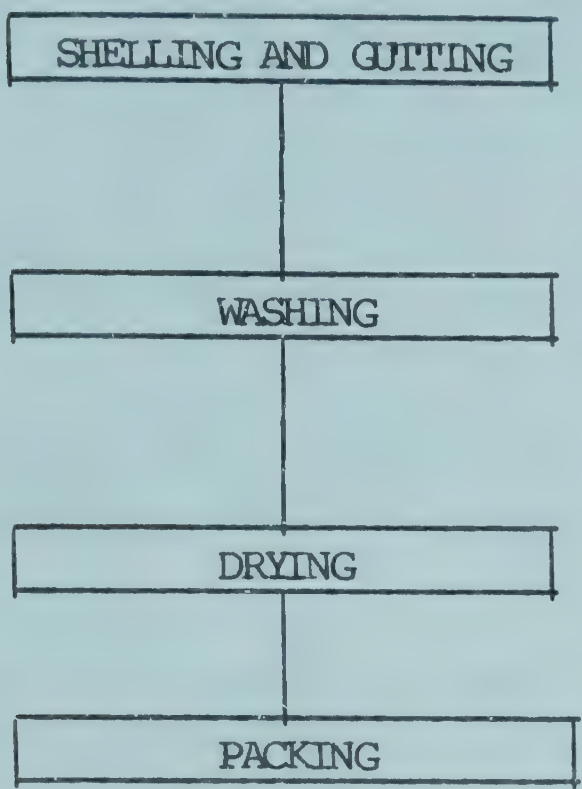
Marketing

The market for this product is the areas near the processing centers and large cities like Chiclayo where dried rays are sold at the MOSHOQUEQUE market. The approximate cost of a piece of 1 kg is US$2. The annual production is estimated at 500 or 800 t.

Dried mussels

Mussels (Mesodenna donacium) are processed during the periods of abundance, that occur as the temperature changes due to the Peruvian current.

The processing method is very simple:



Shells are opened and the content taken out in order to be gutted.

The remaining part of the shellfish is washed with seawater, and the remaining sand removed.

Sometimes salt is added and then dried in spread places.

The dried product is packed in jute sacks of 20 to 30 kg and marketed.

The product is sold in some areas where they are produced, and any excess is sent to other markets.

Dried ishpis

They are small fish captured in the Titicaca lake in the Peruvian highlands. It is perhaps the most abundant species and one of the main food resources of the inland inhabitants of the Titicaca lake. The fish is captured in cat-tail (totora) boats using small seines.

The fish are placed over totora places and left to dry naturally. The drying process is favoured because of the low relative humidity of the area (45 to 60%). The main disadvantage is that the final product is completely oxidised.

A similar product is made of "carachi", which is a larger fish and is gutted before drying. The product is eaten in the communities where it is produced, it is cooked along with potatoes, corn and other crops of the area.

There is no statistical information regarding capture, processing or consumption of these products, but it is felt that they are important food resources of the inhabitants in these areas.

TRADITIONAL PRODUCTION AND MARKETING OF DRIED FISH IN MAURITANIA

by

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Introduction

Mauritania is said to have some of the richest fishing grounds in the world. While this sort of statement may no longer be true, it is a fact that Mauritania has the most abundant stocks amongst the West African countries. Despite this, the nation has up to very recently never been a fishing one and in past times only a very marginal part of its population, the Imraguen fishermen, have been traditionally engaged in fishing. Up till the sixties, the fishermen of the Canary Island, in particular Lancerote, were part of the traditional fishery and are said to have been fishing in Mauritanian waters for centuries. Fishing activities in general and traditional conservation techniques in particular are not very well documented for Mauritania. The information presented here are drawn from only a few dispersed documents, shaky statistics and regarding some aspects a good deal of what could be termed oral history.

In the area of fish drying, mainly three methods are still in use: drying without prior salting, drying of salt-cured fish and drying of fermented fish. To this must be added a specialty, the drying of mullet roe.

Dried fish

Historically, the straightforward drying of fish has played a very important role, since, as mentioned earlier, the small Imraguen fishing communities lived in great isolation along the coast. There were no roads and apparently only very limited access to means of transport by sea. Boats were not used and fishing carried out from the beach. Consequently the catch could only be locally consumed or be preserved by simple drying for either future consumption or trade with the people living in the interior. Before the introduction of more modern fishing methods, the catch consisted of mullet (*Mugil* spp., the main species caught being *Mugil cephalus*), which remain the most important fish dried in the villages. Drying as a method of conservation is the oldest one known to the local fishermen and to this day simple drying of headed and gutted fish plays a significant role in the diet of the fishing communities and reduced amounts are still traded towards the interior of the country. It is to be noted that the moorish or nomadic population has no

tradition of fresh fish consumption, dried fish being to a certain extent treated as an equivalent to dried meat. In any way, salt-cured fish is not consumed on the whole of the West African coast, with many countries giving preference to dried fish, in particular Nigeria which today takes up the largest part of the Icelandic stock fish production.

Concerning Mauritania, production and consumption appear to be stagnating and continue to only play a local role. It is most of all the salt-cured dried fish which is economically important on a regional scale.

Salt-cured dried fish

Salt-cured dried fish is the product for which Mauritania has gained a certain reputation. Given the isolation of the country's only fishing port (founded as Port Etienne in 1909 - Nouadhibou), and the limitations of the freezing industry at the beginning of the century, this was initially the only method of transforming fish and marketing it abroad. The markets already existed in Central Africa, when the Societe' Industrielle de la Grande Peche (SIGP), the company to introduce this activity at the newly founded port, came into existence in 1919. These markets, mainly the Congo, Gabon and Zaire were initially supplied by the Portugese from Angola and by the Spanish from the Canary Islands. The new industry started with an annual production of 1500 t of raw material and at its height in the early sixties transformed up to 10,000 t of fresh fish a year. Nowadays it is reduced to its initial production level and even below, exporting between 200 and 500 t of finished product per annum.

The fish most commonly used is a type of meagre, called "courbine" (Argyrosmus regius). It is caught starting from February/March, when the first fish begins its migration from the south to the north, the height of the season being May/June. Originally fishing was carried out by the artisanal fishermen from the Canaries and at its historical peak a fleet of up to 60 small Canarian seiners were employed. This was supplemented by the Imraguen fishing with their "pirogues" and using so-called "lanches", small vessels with latin sails introduced from the Canary Island and taken over by the locals at the end of the seventies to transport the catch to Nouadhibou. Today, the Imraguen supply almost the totality of the fish still entering the production of this commodity, one or two small Mauritanian owned seiners supplementing.

The fish is headed, gutted, split open from the belly, the spine and main dorsal bones removed. This is done by the fishermen, who also salt the fish, the salt being supplied by the company undertaking the drying. Sea salt is used for this purpose, imported formerly from the Canaries and in more recent times from Senegal. The fishermen then transport the salted fish to Nouadhibou, which by way of a "lanche" takes about a week. At the drying site fish are washed, salted anew with fresh clean salt and brined. At the SIGP, the main producer, the installations consist of large tanks built into the ground which together could hold up to 2,000 t of salted fish in brine storage.

The fish is kept in brine for about a month, then removed, washed, and put onto horizontal drying racks. The drying takes around 2 to 4 weeks, depending on the humidity of the air. Once dried, the fish is cleaned with metal brushes, graded, pressed into bales and packed into jute sacks. Even today jute sacks are the preferred packaging material for the main export market, Congo Brazzaville, and cartons rejected, while transport in bulk is now effected modernly in containers.

The dried courbine, a very large and fleshy fish, make a thick end product which apparently is the most valued of this type on the traditional Central African market. However, it is not the only variety of fish dried. Other fish, comprising most of all seabream (Sparidae), grouper (Epinephelus spp.), spiny turbots (Psettodes spp.), are also salt-cured and dried, providing an end product called "bacalao". This product is treated on the level of the Imraguen villages as well as industrially in Nouadhibou.

In this context a variation of salting and drying utilised mostly by the artisanal fishermen needs to be mentioned. After preparation, which sometimes includes scaling, the fish are washed in salt water, put onto slated racks and then salt is applied to extract water, allowing the liquid to drip off. This process of salting and continued drying is carried out until the salt can no longer draw out any liquid.

Finally, a specialty needs also to be mentioned here, that of dried "tollo", a Squalidae (Mustelus m.) found in abundance in Mauritanian waters. Today, the dried product is still marketed to some extent to Spain, where it has been supplied for several decennies. The fish is headed, gutted and split lengthwise from the belly. After being slightly salted, it is strung up and left to dry. While this is still being practised, most of this type of fish is frozen. Prior to freezing, the fish is headed, gutted and the fins are removed. At least one enterprise has been seen to dry the fins. The quantities obtained are very small and are said to be marketed to Spain - for what type of consumption is unknown.

Fermented and dried fish

The production of fermented and then dried fish appears to have been introduced after World War II by fishermen coming from the Senegal River and from Senegal, the Thioubalo, a caste of the Hal Poulard and the Wolof. All of these fishermen were attracted by the expansion of fishing activities in Mauritania and nowadays are working mostly seasonally at Nouakchott and Nouadhibou. The product is called "Guedj", a Poulard word, and is a traditional ingredient in the diet of the negro-african populations living in Mauritania and in Senegal. As far as is known, "Guedj" is most of all produced in Nouadhibou, with only minor amounts coming from Nouakchott. It is mostly marketed within Mauritania, but allegedly traded as far as Mali and perhaps Niger.

The fish used are leer fish (Lichia amia), spiny turbot (Psettodes spp.), catfish, (Muraenidae spp.), seabream (Sparidae spp.) and mullet (Mugil spp.), but also other varieties and in fact, any bony fish is suitable. It is important to note here that for the fishermen the production of "Guedj" is a way of transforming fish which is no longer fresh enough to be marketed or which remains as a surplus - a type of raw product utilisation which does not enhance the quality of the finished food item.

The fish is first scaled, then headed and gutted, cut into pieces and finally fermented in vats for about 24 to 72 h. The fermentation is carried out with or without seawater, depending on the season of the year. During the colder months the water is omitted, while during the hot season salt water is added to slow down the fermentation process. After fermentation the pieces are dried, a process which takes between 4 to 10 days, depending on the type of fish and the season of the year. Fatty fish takes longer, lean fish a shorter time to dry. As far as consumer preference is concerned fatty fish such as mullet are preferred for this reason, lean fish is dipped into fish oil on the second day of drying, in order to give the fish the yellowy colour preferred by the customers. The end product still contains a relatively high percentage of moisture (30 to 50%) and under the prevailing climatic conditions does not keep for more than a month.

"Guedj" is consumed either as a sort of spicy addition to the originally Senegalese national dish "thiboutienne" (rice with fish) or in a dish called "thibouguedj", where it is the main ingredient in the rice. In Mauritania, "thibougtienne" is nowadays also consumed more and more by the non-negro-african population and as a fact it can be seen from existing statistical material that the national consumption of "guedj" has increased considerably, from about 50 t in the early eighties to over 200 t last year. However, this is still a long way from the consumption level registered in neighbouring Senegal, where in 1984 3,500 t of "guedj" were consumed.

Dried mullet roe: poutargue

Dried mullet roe was introduced by the French managing the SIGP around 1936 as a way of utilising the roe of the mullet, the main species caught by the Imraguen. The product is called "poutargue" in French and is known under similar names in other latin languages. Dried fish roe is a delicacy known for a long time around the Mediterranean and is especially valued by the Jewish community. "Poutargue" produced in Mauritania is solely exported to France, where the center of consumption is Paris and there again most of all the Jewish population.

The production is purely artisanal and undertaken during the mullet season, which lasts from October to January. The mullet itself is either simply dried, salt-cured and dried or turned into "guedj". The ovaries are removed from the fish and care is taken that the skin surrounding them is not

damaged. Drying takes place on wooden slabs or the roes are spread over netting stretched between poles.

Drying time is estimated to be 1 to 2 weeks. The dried product is delivered to an exporting company, which coats the roes in wax and wraps them individually in paper. The wax coating prolongs storage life and in fact, the "poutargue" can be kept for up to a year, if stored at low temperature.

Traditionally the "poutargue" is consumed thinly sliced on bread, eaten in this way, it has a rather particular and strong taste. Perhaps for this reason and in order to enhance consumption, a different way of presentation has been introduced. The "poutargue" is grated, spiced with pepper or chili sauce, lemon juice is added and this mixture blended with butter. Official statistics indicate, that a tonne of this product is exported annually. Paris is said to consume 17 t of "poutargue" a year, other sources of supply being Tunisia and Australia, where the "poutargue" is manufactured with modern drying methods and irradiated, the end product being of very regular quality and presentation but apparently lacking the taste of the Mauritanian or Turnisian variety.

Outlooks

Today, Mauritania is building up a modern fishing industry which is presently oriented towards the production of frozen fish. In relation to this, more traditional forms of conservation are losing ground either because of lack of quality and/or difficulties of production and market access. The most pertinent case is salt-cured dried fish. With the withdrawal in the sixties of Mauritania from the Franc-Zone and the introduction of a currency of restricted convertibility, the activities of the Canarian fishermen ceased and the gap opening up in the raw material supply could not be closed by the local artisanal fishermen.

Today, artisanal fishermen find more attractive prices when selling to the freezing industry or marketing fresh fish supplied to the urban centres leading to a reduction of fish being supplied to drying establishments. As well, the quality of fish supplied to these is said to to be reduced. That the SIGP's own outlet in the Congo had to be given up due to Mauritanian economic policy which initially forbade participation of Mauritanian in foreign companies and the creation in the Congo of a state import monopoly did not help the marketing situation. While the market in the sense of a taste and the need is said to still be there and can not be adequately supplied, present condition work against the development of the traditional outlets.

BRINING AND PRESSING OF SMALL PELAGIC FISH AS AN ALTERNATIVE TO TRADITIONAL PROCESSING

by

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Introduction

In many tropical locations where catches of small pelagic fish are landed, the need exists for a process by which the fish can be preserved long enough to be transported to distant markets or stored until landings decline. Whilst traditional sun-drying gives products with good storage properties, the process can only be used when fine weather is assured; the resulting products are easily damaged by transport, adverse storage conditions, and infestation. Furthermore, fatty fish give a strongly rancid product, with little consumer appeal.

The method described here is a cheap, simple process for use under ambient tropical conditions, developed in London at TDRI for sardines and tested in India towards the end of 1985. Although sardines (*Sardinella longiceps*) were used in this case there seems no reason why other small pelagic fish could not be prepared in the same way.

Principle of the process

Fish are beheaded, eviscerated and washed, to remove digestive enzymes and prevent the excessive autolysis which is found to occur when whole fish are used. The fish are then deposited as soon as possible in saturated brine and stored until equilibrium is reached between the brine and the fish flesh. Preservation of the fish, and bacteriologically safety are assured principally by efficient brining, which should reduce water activity (Aw) of the fish flesh to a value of 0.85 within the first 48 h of brining. Even under otherwise ideal conditions this should prevent growth of all food-borne pathogens, including salt tolerant *Staphylococci*. A final value below 0.83 is essential in order to prevent the slower growth of xerophilic fungi, some of which have been shown to produce mycotoxins at Aw values above 0.83. Provided brine strength is maintained at 90% saturated or above (check using a hydrometer or salinometer) uptake of salt is found to be fast enough to ensure a safe product. Figure 1 shows salt uptake by sardines. The fresher batch of fish take up salt more slowly than the 4 to 5 h old batch, but are nevertheless in a satisfactory condition 3 to 4 days after the beginning of brining. Larger fish would obviously take longer to come to equilibrium with the brine.

Following brining the fish are placed in orderly layers in a loose bottomed, slatted box, and pressed to remove excess moisture. The fish form a compact block, from which air spaces are excluded as much as is practically possible; this treatment appears to retard rancidity considerably. The pattern for packing sardines and plan of the pressing box are shown in Figures 2 and 3.

The block of fish is finally transferred to a polythene lined carton, by standing the box on a support, and slipping the carton over the top of the pressing box. During this process the block is not disturbed and once the polythene flaps are tucked in or sealed the fish are ready for storage or transport.

Trials under tropical conditions

When brining was carried out under tropical conditions, salt uptake (shown in Figure 1) was fast enough to ensure microbiological safety, as indicated by microbiological examination of the fish during processing. Although the fish initially contained small populations of both Staphylococci and coliforms, none were recovered after brining. Fungi could be recovered throughout processing and storage, but did not appear to grow on the fish, only starting to spread on the surface of the block after ten or twelve weeks storage. Detectable amounts of histamine were present after brining, as would be expected when processing is carried out at ambient temperature. During the first six weeks storage, this value increased, but only to a maximum of around 6 mg/100 g flesh; an acceptable level for this kind of product.

The effect of storage on quality was assessed by a group of trained tasters, who were presented with four samples of desalted steamed fish, stored for different periods of time. The results (Figure 4) show how there is a little change in quality in the first three weeks of storage. After this some loss of quality did occur, particularly with respect to flavour. Loss of quality appeared to be connected with an increase in rancidity, and this was the reason given by most tasters for marking down some samples. Although the tasters' results agreed as regards differences in quality between samples, some tasters gave consistently higher marks than others. This problem is likely to arise in cases such as this, where there is no well known product with which to compare, and no standard limit of acceptability. Regardless of this it is clear that the product can be stored for up to at least six weeks without a great loss of quality.

Consumer acceptability

Brined and pressed sardines which had been stored for two weeks were washed to remove most of the salt, then prepared as a curry, as would be the custom locally. The fish curry was served to the diners at a canteen, used by students, college staff and local factory workers. Questionnaires were given to the diners after their meal, and the responses collected. Results are shown

Figure 1 Water acitivity of sardine flesh during processing and storage

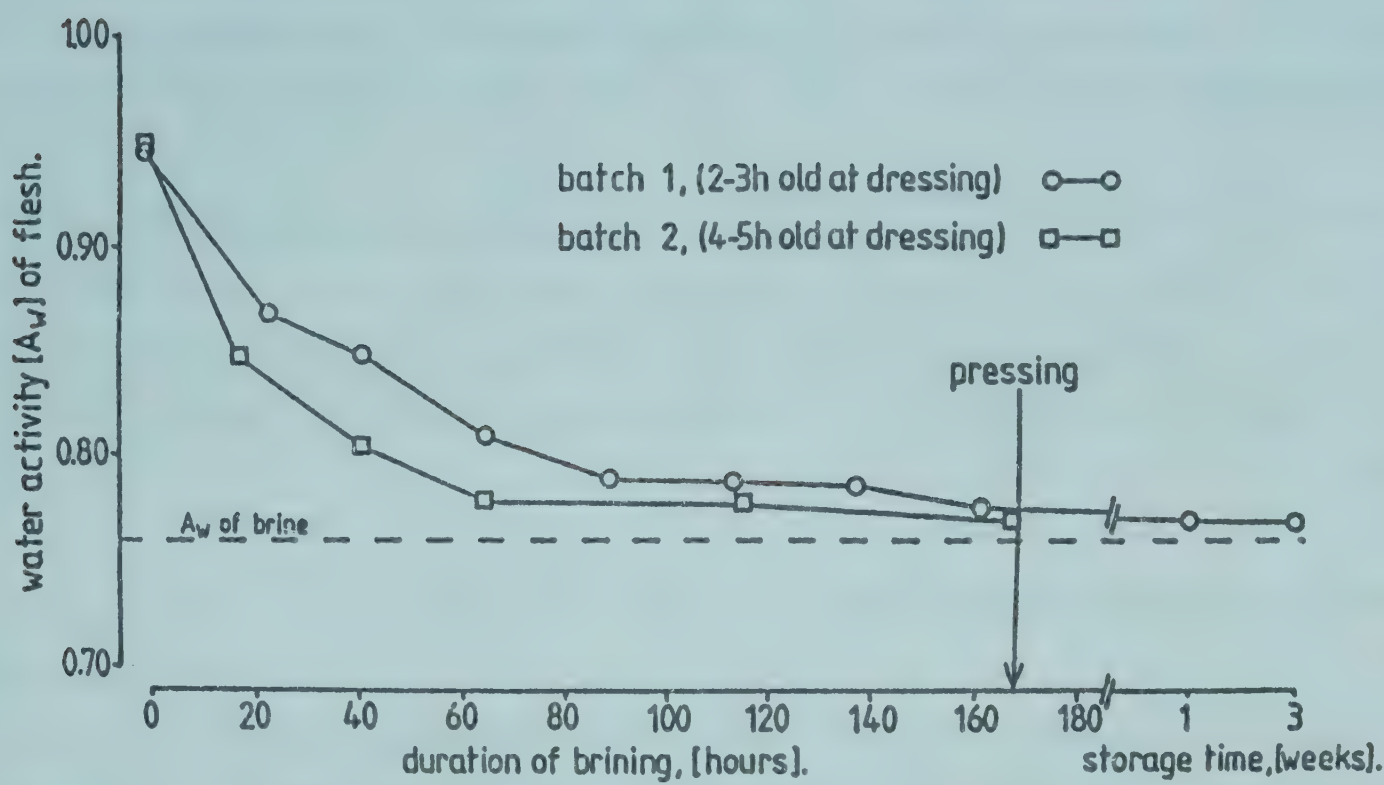
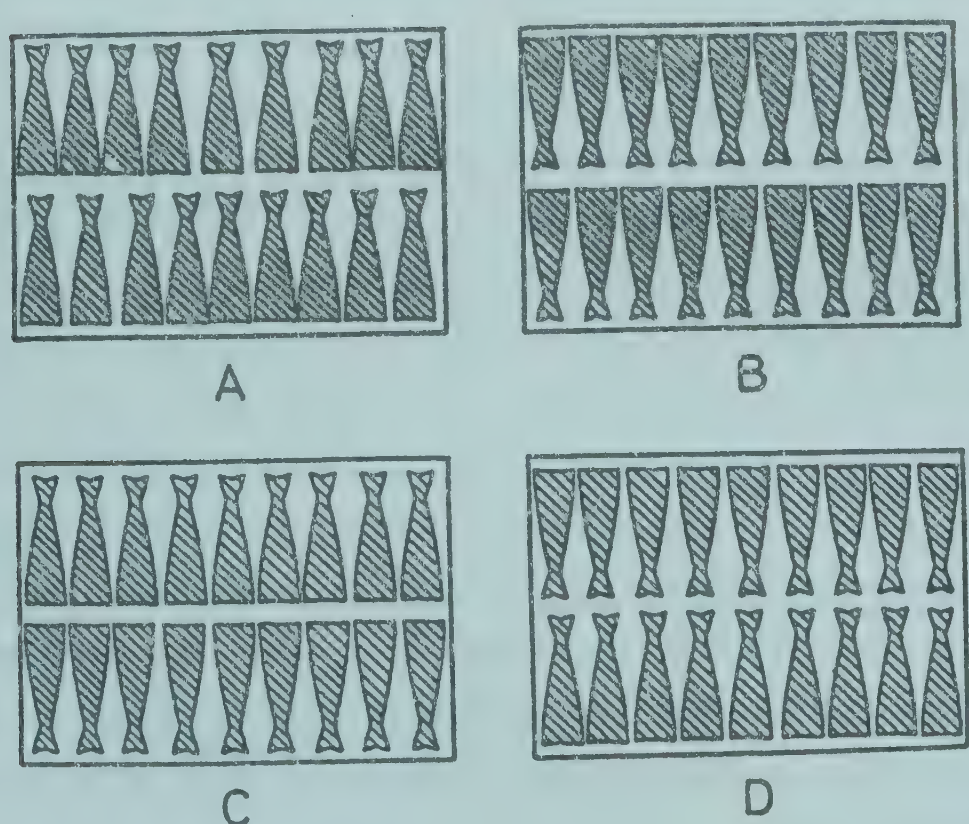


Figure 2 Packing of sardines in the pressing box



Pack alternate layers in patterns A and B.
Substitute patterns C and/or D when necessary, to keep the surface of the block level.

Figure 3 Design of pressing box

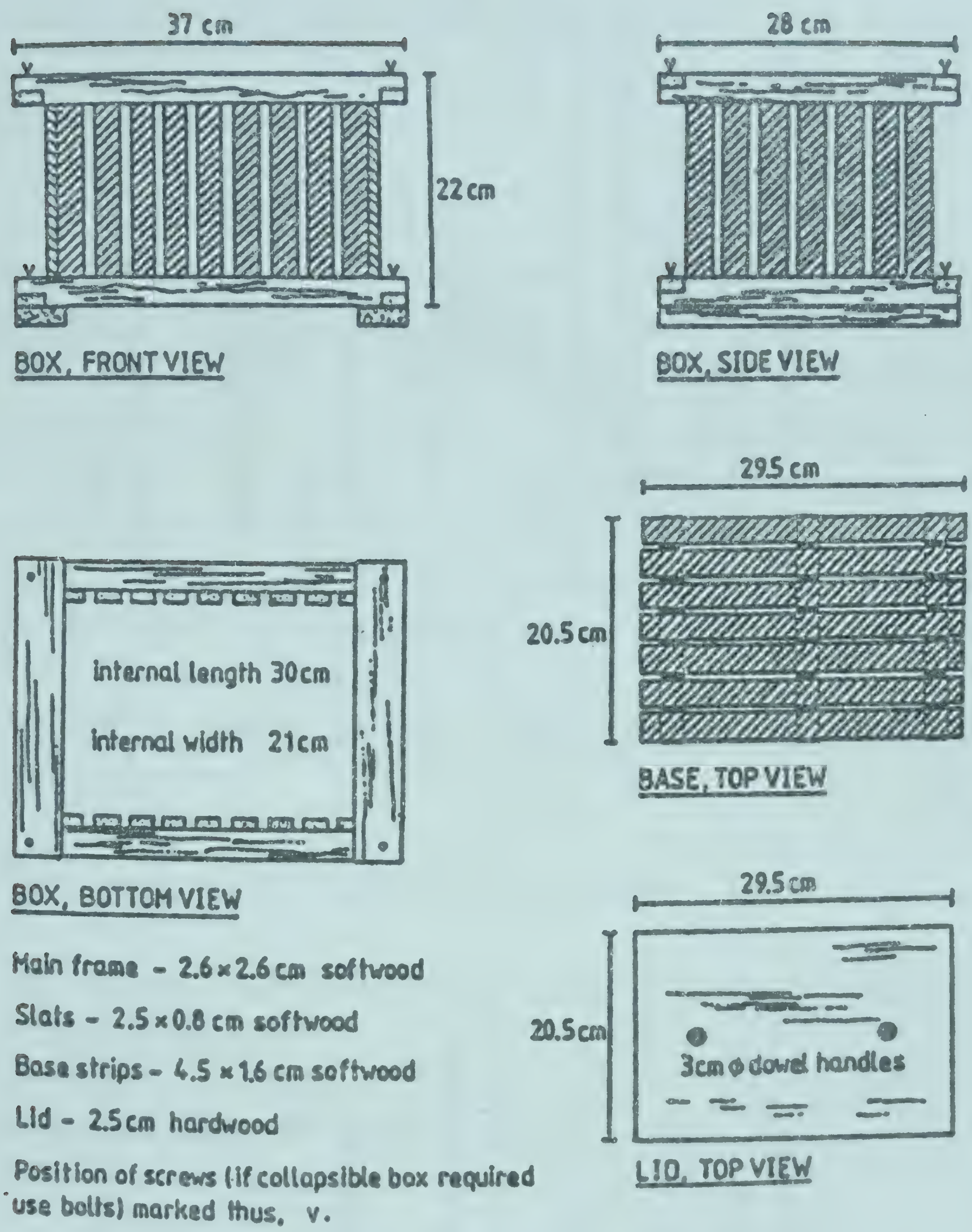


Figure 4 Effect of storage on organoleptic quality of brine pressed sardines

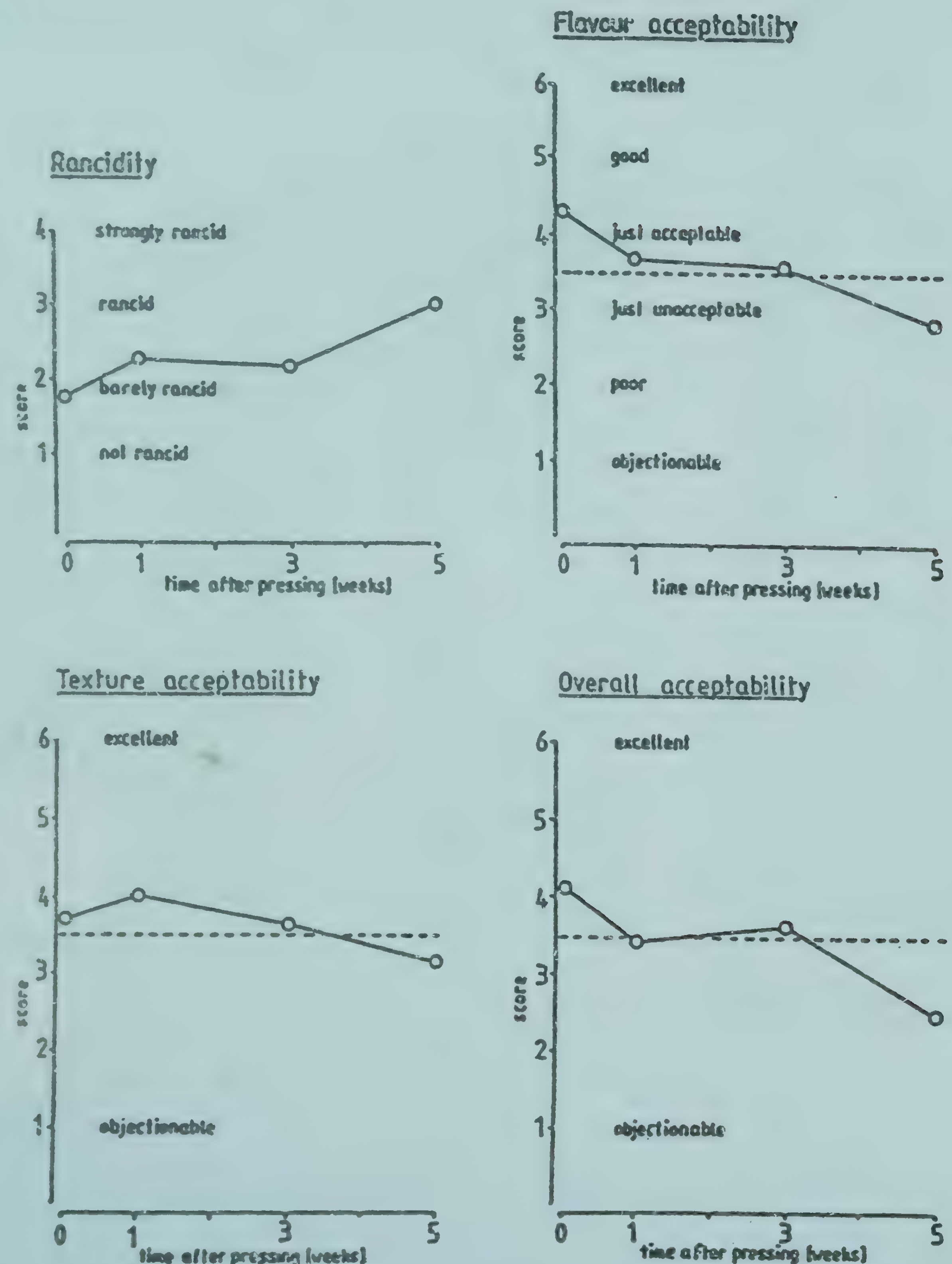
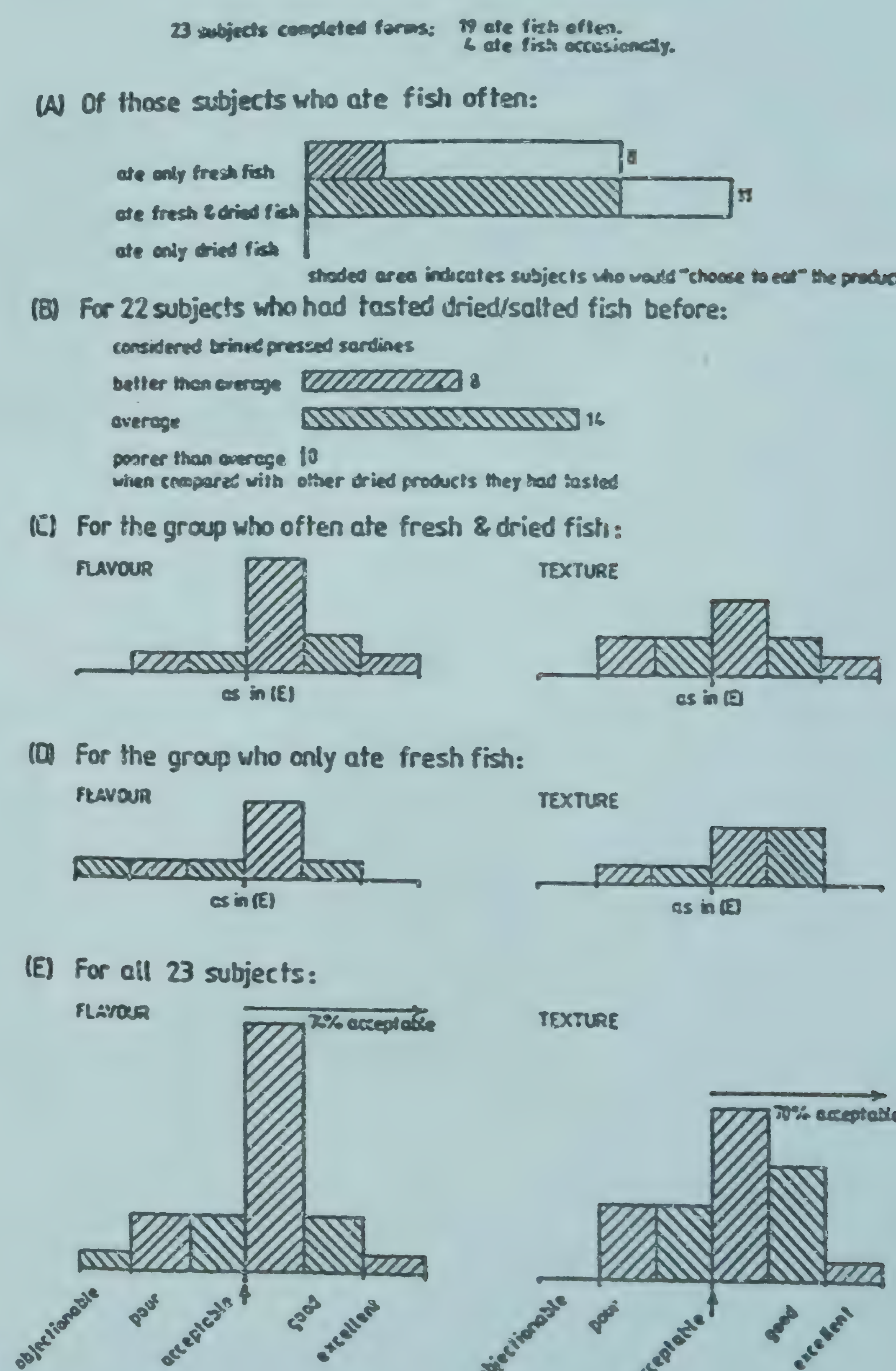


Figure 5 Consumer response to brined pressed sardines when prepared as a curry



in Figure 5 which clearly show that the product was liked by those subjects used to eating dried fish. Additionally, those who did not normally eat dried fish, whilst they may not have liked the product, tended to prefer it to traditionally cured fish. On the whole the product was eaten and liked, and many subjects said they would buy it if it were commercially available. Consumer comments suggested that the product may have invited a more enthusiastic response had it been presented spiced and fried; a more suitable preparation in the opinion of nearly all the tasters.

Applications of the process

From the results of the trial it was felt that although sun-drying is cheap and often produces an adequate product, the brining and pressing process could be appropriate under certain circumstances, provided salt was cheaply and readily available. Conditions which may make use of the brining/pressing process worthwhile include the need to reduce losses due to infestation and fragmentation, particularly when it is intended to transport the product. Weather conditions unsuitable for sun-drying or storage of a low moisture product may also make the use of this process desirable, allowing fish to be processed and kept over the rainy season.

Work aimed at improving the product by retarding the development of rancidity is now underway.

Recommendations for brining and pressing sardines

The following recommendations are made on the basis of experimental processing between 20 and 30^{o}C.

About 30 kg of undressed sardines are required to fill a box approximately 20 cm x 20 cm x 30 cm (as in Figure 3).

DRESSING

Fish should be fresh and chilled if not immediately brined.

1. Remove heads and guts as soon as possible
2. Wash in clean water

BRINING

Salt does not always dissolve readily especially as brine strength increases. Thorough and frequent stirring is needed.

Saturation should be checked daily (after stirring) with a salinometer (hydrometer) and greater than 90% saturation maintained. Remember the fish will gain salt and lose water, diluting the brine as they do.

It is important to keep the container closely covered throughout brining.

3. Make brine by stirring together 600 g of salt and 1 litre of water, for each 1 kg of dressed fish. Check saturation is 90% before adding fish.
4. Immerse dressed fish in brine, using a weighted plate to keep top fish immersed. Cover.
5. Stir thoroughly twice daily, testing to make sure brine is 90% saturated, and some salt remains.
6. If no salt remains, add extra salt and stir well.

PRESSING

Provided brine strength has been maintained, fish will be thoroughly brined after 6 days.

7. Drain fish from brine.
8. Pack into pressing box (see Figure 3)
   Keeping layers as closely packed and flat as possible.
   Do not allow fins to project through slats.
9. Apply weight to pressing lid and leave for 8 to 18 h covered if possible.
   The box shown in Figure 3 requires about 25 kg weight.
   (400 to 500 kg per m^2)

PACKING

Use box strong enough to support block, fixed with waterproof glue.

Use 400 gauge (approx. 100 um thick) gussetted polythene bag or preferably, two layers of 250 gauge bag (approx. 60 um thick) to line carton.

Box should be nearly filled, or corners slit and turned in after filling to prevent crushing.

10. Line carton with polythene bag, fitting into the corners, and turning open end over the edge of box.
11. Remove pressing lid. Slide into polythene lined carton, then remove slatted base.
12. Fold over polythene. Seal if desired. Cover with lid.

IRRI WAREHOUSE DRYING SYSTEM

by

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1. Introduction

1.1 Background information

The need for "appropriate" post-harvest technology for tropical regions has been repeatedly emphasised. Despite available information, the state of post-harvest technology in most developing countries is still wanting in both sufficiency and efficiency.

Drying is one of the most critical post-harvest operations which should be carried out immediately after harvest in order to prevent deterioration. In Southeast Asia, the more common practice of drying is by sun-drying. The unreliability of a continuous sunny day makes it difficult to rely on sun-drying alone. Thus, a need for mechanical dryers.

The idea of mechanical drying which is parallelled to artificial drying has long been introduced in the Philippines and elsewhere in Asia. In the past, mechanical dryers were imported from the temperate countries but did not find satisfactory acceptance in the tropics mainly because of climatic differences and the fact that these dryers are crop-specific, highly technical and expensive.

Recent research have focused on the development of on-farm drying facilities. There have been attempts to utilise available sources of energy like rice hull and solar energy but the use of mechanical and electrical power for the blower or fan is always coupled to the system. This is one of the reasons why these dryers are often not used in the rural areas; electricity is not always found in smaller towns and farms.

Countries in the tropical region have greater potential for the use of non-conventional sources of energy as an alternative energy source for drying. A well-designed grain drying system using non-conventional energy could reduce drying costs as it can be developed along the concept of an intermediate technology wherein the system is simple in construction, low in cost, makes use of materials available in the region and can be used for multi-purpose need.

Accordingly, the International Rice Research Institute (IRRI) developed a warehouse type dryer based on the principle of natural convection and utilising the wind and agricultural residues as energy sources.

This paper provides a general description of the dryer and its components, as well as its operating characteristics.

1.2 Design consideration

The most important consideration in the design of the dryer is the scarcity of fossil fuels and the unreliability of a continuous electrical power supply in the rural areas where the dryers are most needed. However, there is abundant supply of alternative energy sources such as agricultural wastes (rice hull, rice straw, corn cobs, etc). Wind and solar energy are natural energy sources which can be tapped for any designed applications.

The post-harvest system is viewed as a whole picture comprising generally of the less economically fortunate farmers who produce different commodities in different quantities during different periods.

Experience in the introduction of post-production techonologies, specifically of the mechanical dryers, emphasise the need for a careful integration of technical, economic and social nature/characteristics of the locality to be served in order to attain a satisfactory response from the end user.

Considering a wide variation in dryer requirements in various localities, design of area and crop-specific technologies may not prove economically viable. Thus, the design of a warehouse dryer was conceptualised and made operational.

1.3 Description of the IRRI dryers

The IRRI-developed warehouse drying system is a multi-commodity drying and storage facility which utilises non-conventional energy source. The system combines the traditional and artificial drying methods. It consists basically of a furnace, a vortex wind machine (VWM) and the material holding trays. These components comprised a warehouse structure designed to dry and/or condition materials by natural draft.

The furnace is of soil brick construction and can be fueled with agro-waste materials such as rice hull, corn cobs, coconut husk and others.

The vortex wind machine is a stationary cylindrical tower consisting of slotted vertical vanes symmetrically arranged about a central axis. Energy from the wind is used to create suction draft in the system for drying and aeration.

The drying materials are held in a row of vertical trays made of wooden frame and wire mesh designed with adjustable louvers. Drying different commodities can be achieved in batch or in separate lots at one time.

Further, the warehouse drying system provides an intermediate, low cost drying and storage facility which can be constructed by the farmers themselves from locally available materials.

Several types of the warehouse dryers were developed for varied applications (Appendices 1a, b, c).

A unique feature of the warehouse dryer is its capability to dry commodities other than grain crops. Appendix 2 describes the dryer used for fish drying. For this particular direct-fired dryer, rice hull charcoal briquettes are recommended as fuel materials. Hence, a rice hull carbonizing technology was developed as described in Appendix 3.

2. Design and performance details

2.1 Furnace

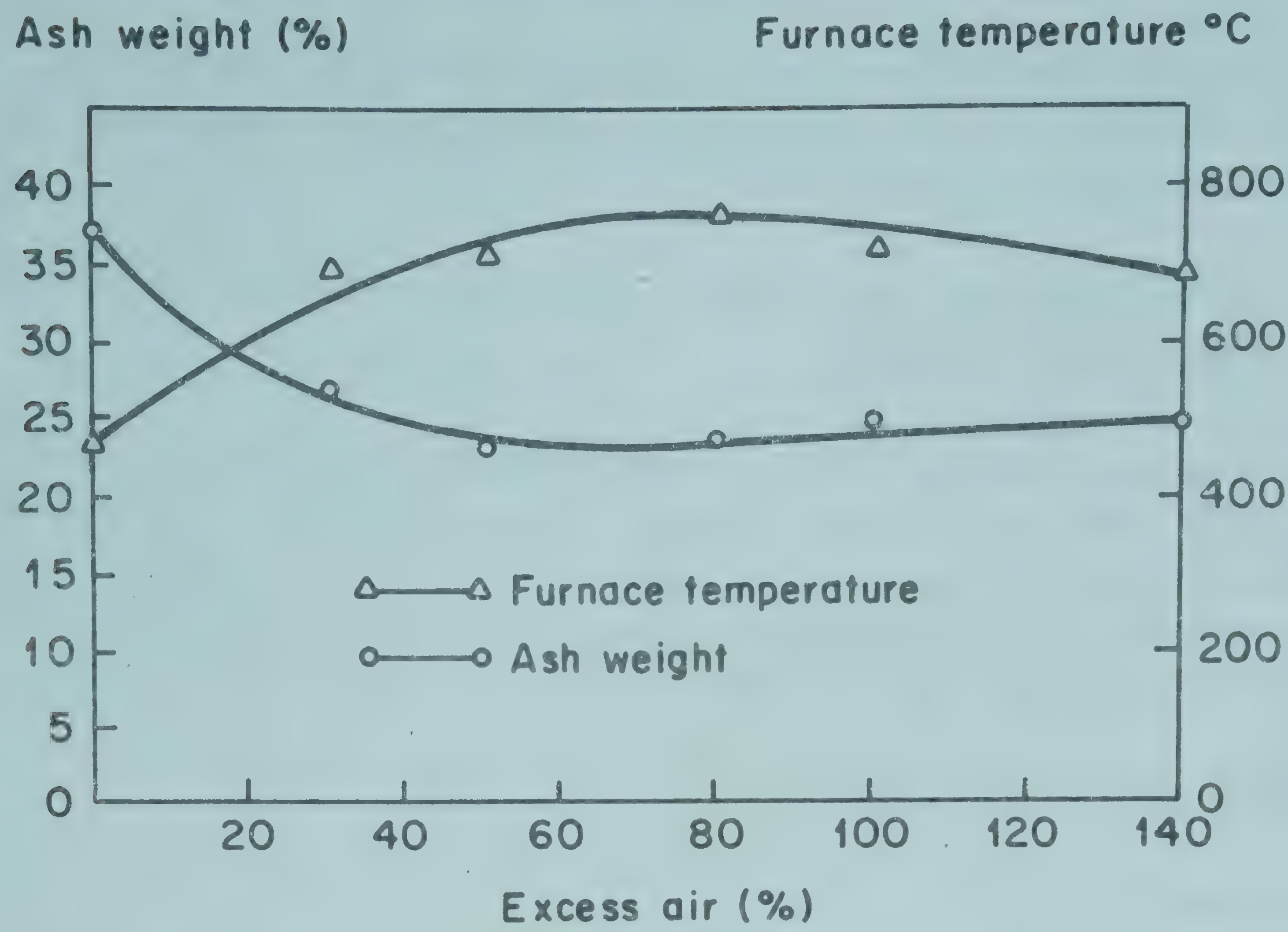
2.1.1 Design criteria

The furnace was developed based on the results of basic experiments conducted. Some of the physical factors considered were: airflow rate, size of burning chamber (fuel bed), temperature of the fuel bed, ratio of primary and secondary air and size of the fuel material.

Analysis of the chemical reaction of the different air constituents with oxygen during the combustion process gave a theoretical air requirement of 3.733 m^3 (4.807 kg) to burn one kg of rice hull.

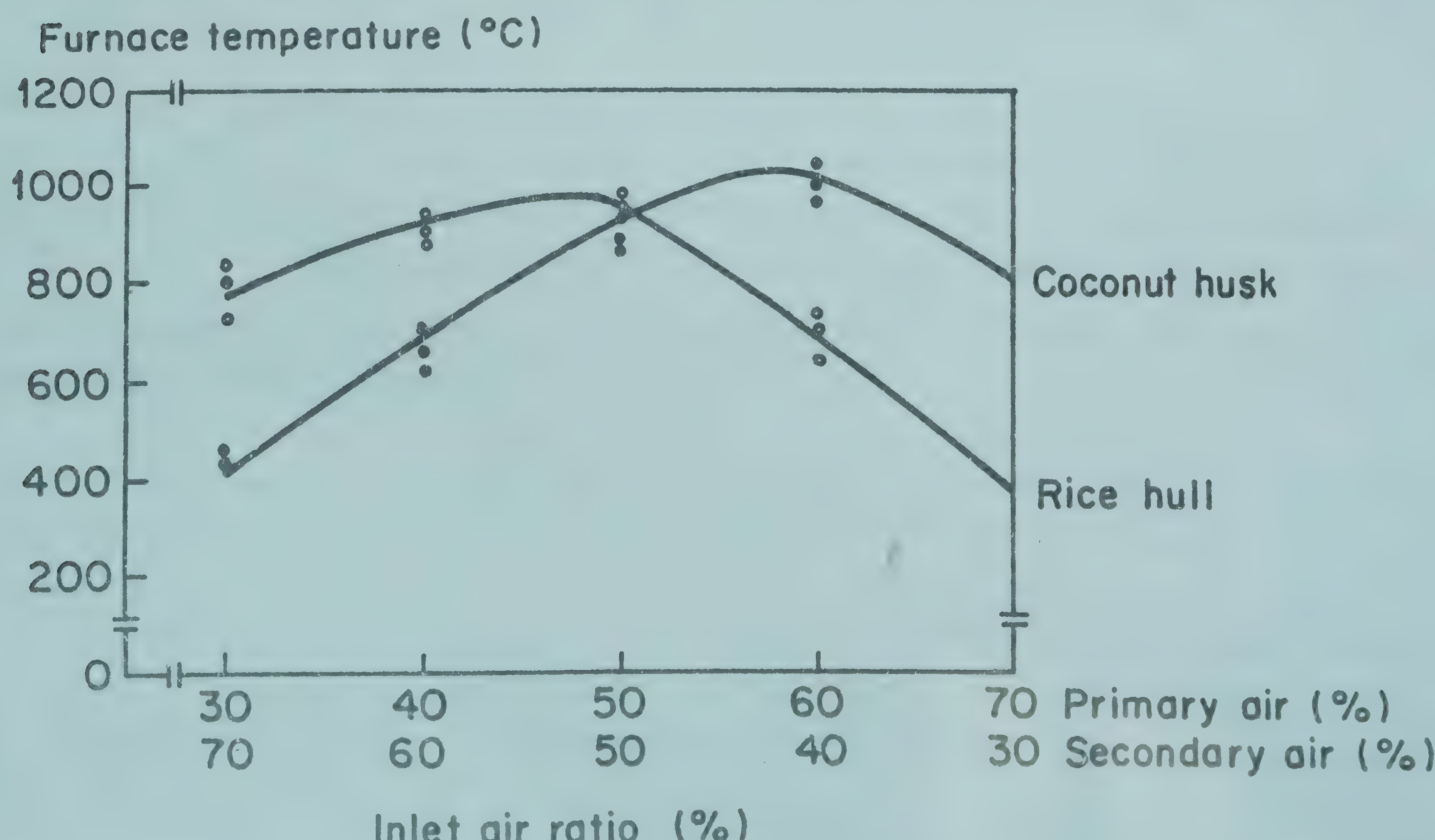
An amount of excess air of 65 to 75% of the theoretical air is needed to completely burn the material (Figure 1). This amount of excess air should be supplied in the proper amount and proper proportion to the system. It can be accomplished through the primary and secondary air inlets.

Figure 1 Effect of excess air on ash recovery and burning temperature



Different materials require different amounts of primary and secondary air. Rice hull burns with a supply of primary and secondary air at the same proportion. Coconut husks, on the other hand, needs more primary air (about 58%) as its components break down easily during the primary phase of combustion (Figure 2).

Figure 2 Effect of primary and secondary air ratio on furnace temperature

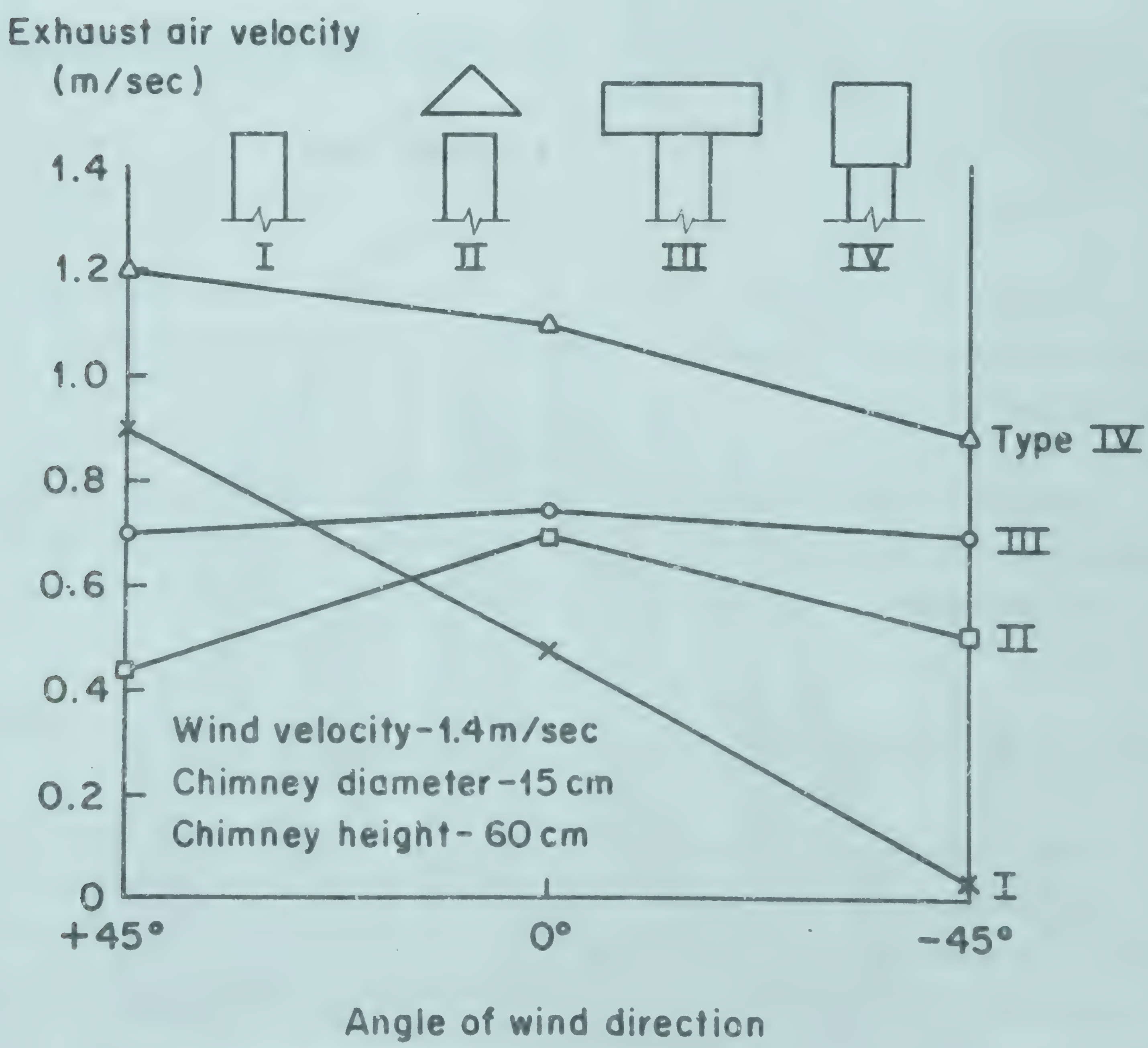


The physical properties and the burning characteristic of the materials were also considered. These two properties describe the flow of materials in the fuel bed and the extent to which the volume changes during combustion. They also define the material feed interval to sustain a temperature that will support continuous burning.

Chimney top shape and dimensions were determined from a derived relationship between chimney dimensions and exhaust air velocities. For satisfactory combustion of agricultural wastes, the exhaust air velocity must be within 70 to 90 m per min.

A T-chimney was selected since it is not significantly affected by the wind direction (Figure 3). Satisfactory design dimension for the T-length was estimated as 3D (D is the diameter of the chimney tower).

Figure 3 Performance curves of four types of chimney top shapes as affected by wind direction

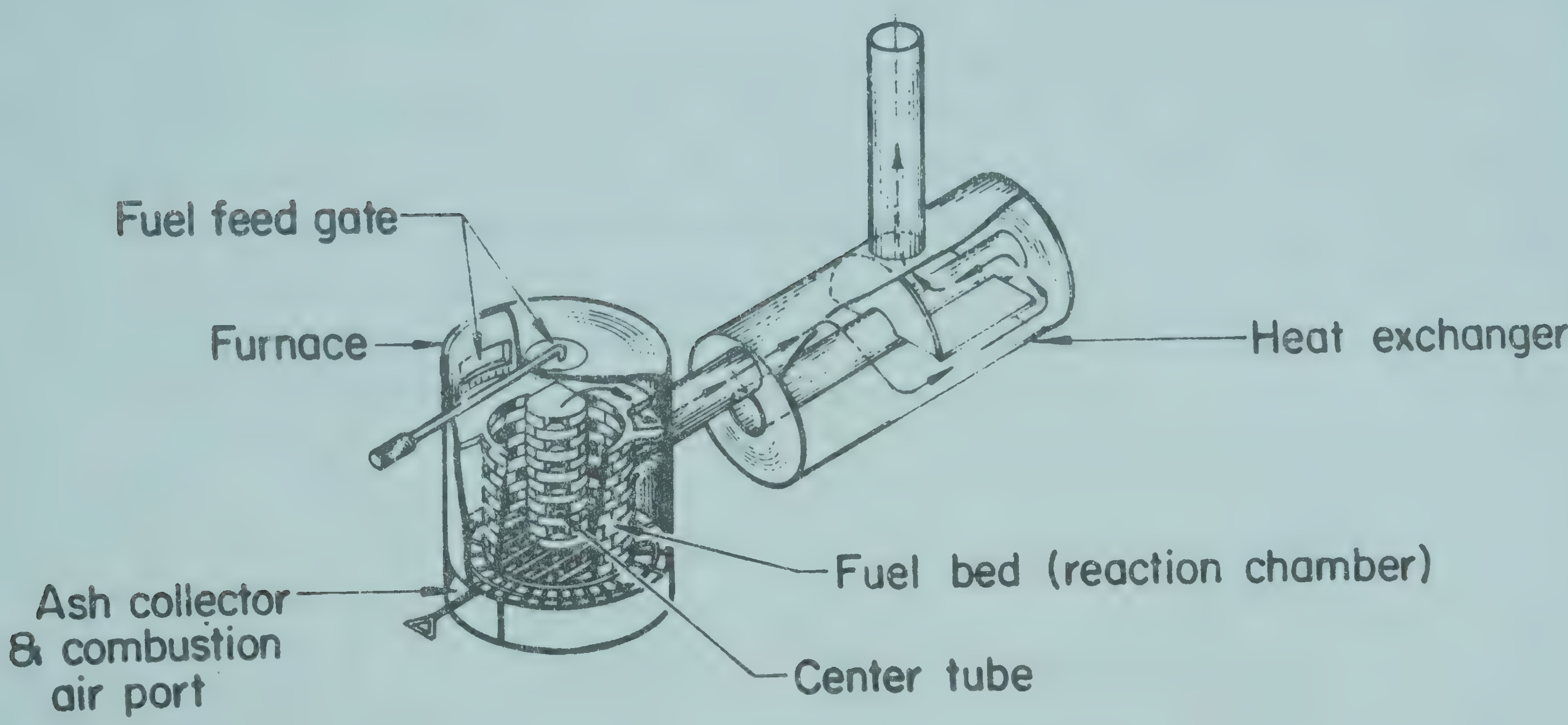


Based on these considerations, the center-tube furnace was developed.

2.1.2 Design details

The center-tube furnace (Figure 4) consists essentially of a burning chamber, a hopper, a chimney and the ash damper. The furnace can be constructed from used oil drums or from soil-ash bricks.

Figure 4 Cross-sectional view of the center tube furnace



Materials are burned in the fuel bed which is enclosed by the intermediate and innermost cylinders. Combustion involves carbonization and gasification processes.

Material feed rate is controlled manually at 5 to 15 minute-interval depending on the fuel material and the temperature maintained in the burning and drying chambers. Ash damping is accomplished through a manually operated foot lever.

2.1.3 Performance details

The center-tube furnace was designed to burn any kind of agrowaste fuels with emphasis on the combustion requirements of rice hulls. The factors affecting the combustion efficiency are moisture content of the fuel, porosity of the material in the bed, the fuel bed temperature and the combustion air supply.

An ideal heat utilisation possibility was observed from the furnace. The furnace temperature can reach as high as 700°C. The feed rate is controlled at a pre-determined interval to maintain a chamber temperature of at

least 400^{o}C. This temperature results to a burning efficiency of at least 95% when moisture content of the fuel material is below 16%.

The amount of heat generated can be used for an equivalent paddy drying capacity of 6 to 8 t per day with drying air temperature of 35 to 45^{o}C and a water heating capacity of 250 L per h (i.e. increasing the water temperature by 10^{o}C).

3. Vortex wind machine

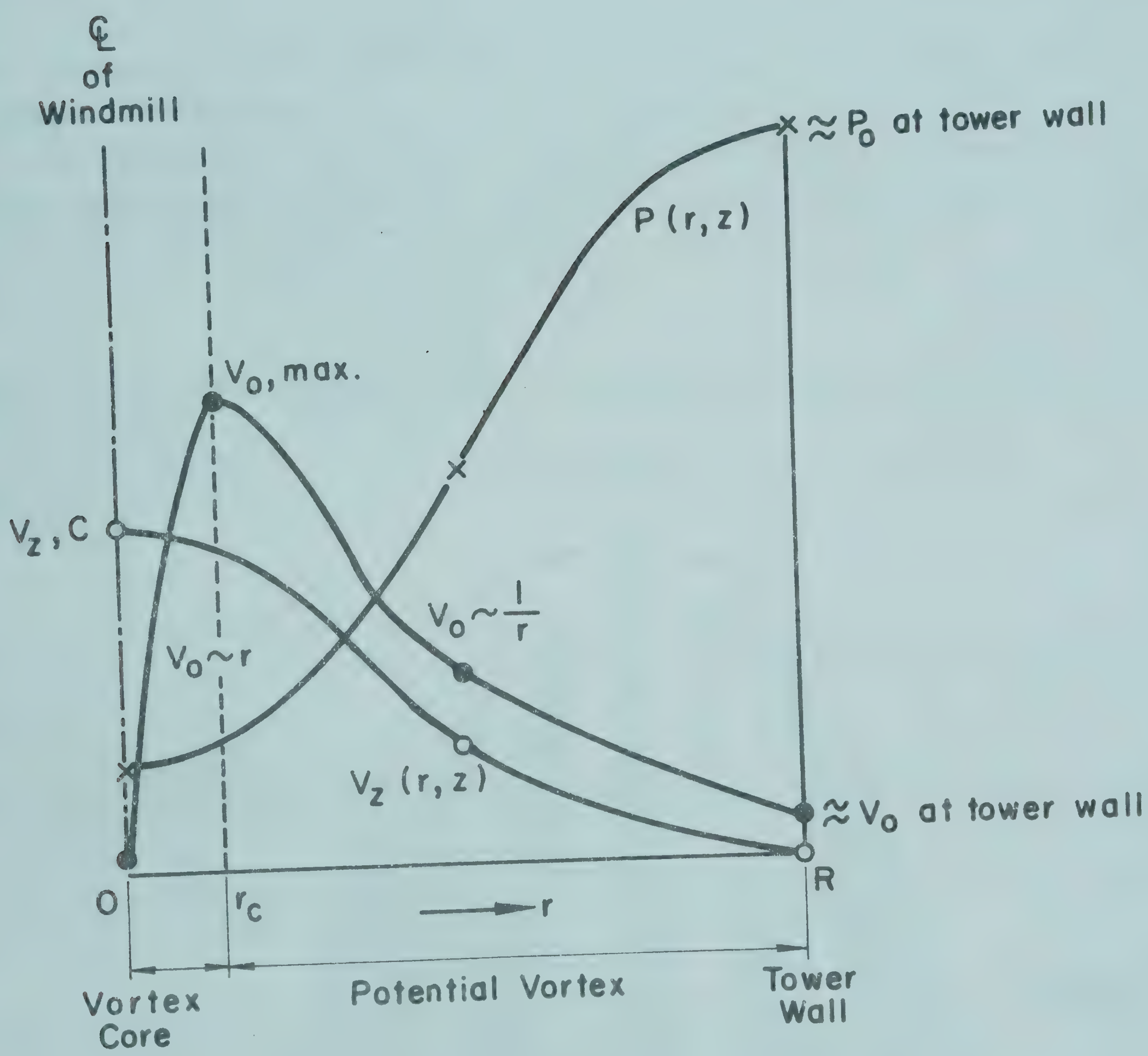
3.1 Design details

The vortex wind machine (Figure 5) is a vortex generator tower consisting of opened- and closed-vanes enveloping an area which is capable of generating suction pressure. A low pressure area at the core of the tower results from the circulating velocity of wind striking the vane. This property of the tower renders it applicable for expelling or circulating air from any structure beneath it.

Figure 5 The Vortex wind machine (VWM) wind air-foiled vane configuration

Based on aerodynamic concepts design calculations for vortex dimensions resulted in defining points for maximum and minimum velocities and pressures from the vortex core to the tower wall (Figure 6). This leads to the determination of the potential vortex dimensions, that is, if D is the diameter of the top of the venturi structure, then the diameter of the tower is approximately equal to 3D and the height is 9D.

Figure 6 Wind pressure and velocity pattern for a closed-bottom vortex with nearly uniform V_z



3.1.1 Performance details

The minimum velocity for safe drying using the developed wind machine is 0.75 m/sec. Analysis showed that 18 h can be used for safe drying when the developed wind machine is applied (for average wind velocity of 1.4 mps).

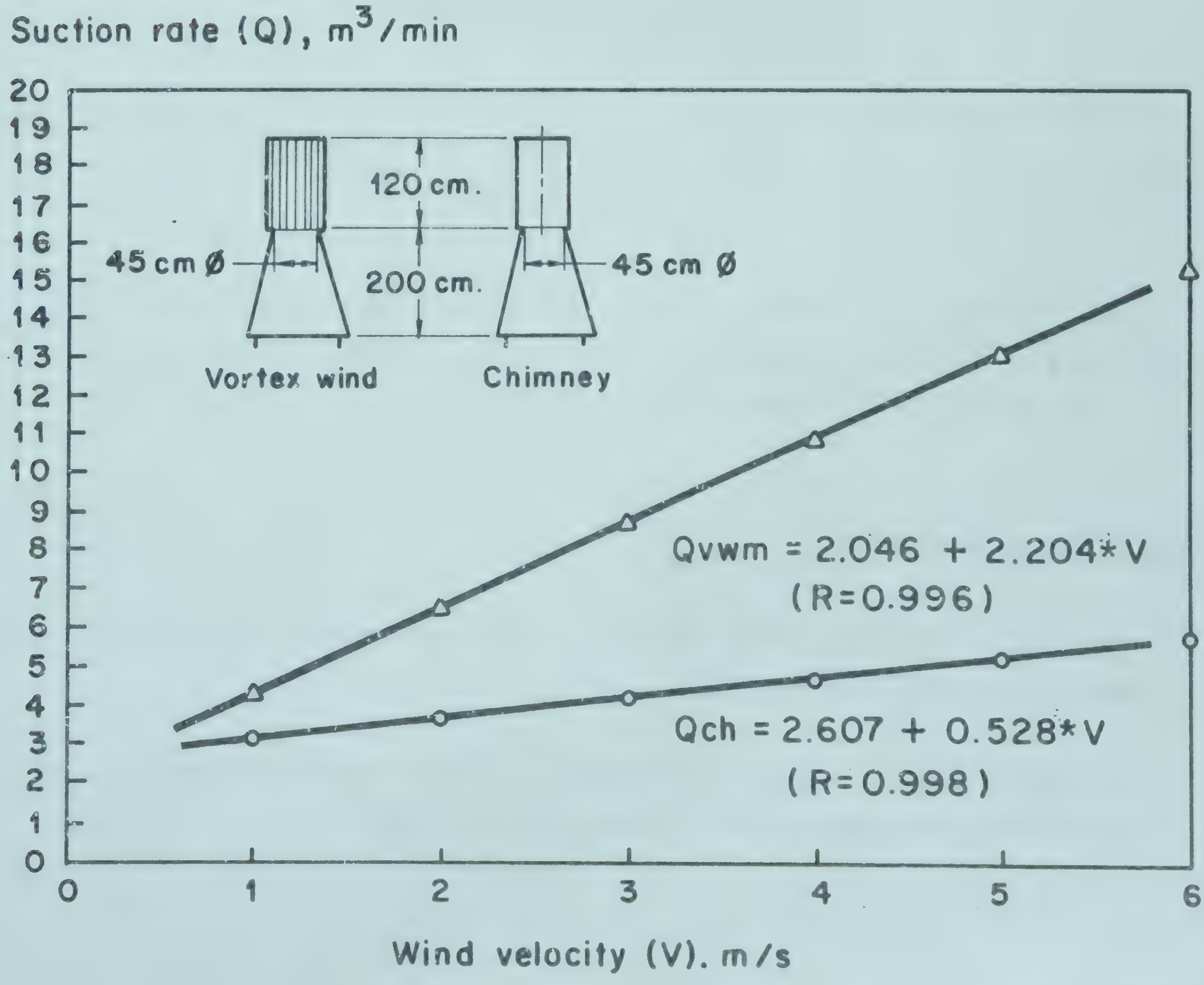
Wind velocity is observed to increase 3 to 4 times using the wind machine depending on the wind collector performance. However, a properly designed vane will improve its performance.

The vertical velocity in the core increases as the diameter of the vortex is increased. For large-scale systems, the vertical velocity in the core could reach values that are at least 7 to 8 times the angular velocity of the wind at the tower wall which is about the speed of the wind entering the tower.

The contribution of the wind machine to the overall dryer performance is characterised by its relative contribution to suction flow rate as a function of the varying outside wind condition, the structure itself and the temperature gradients.

The VWM was observed to provide a steady airflow from the dryer increasing the chimney effect by more than 3 times (Figure 7). This observation relates to the capability of the VWM to create a confined vortex which is reflective of the effectivitiy of the slotted vertical vanes. Thus, in addition to harnessing the wind kinetic energy, the VWM is also capable of deriving energy from the pressure field.

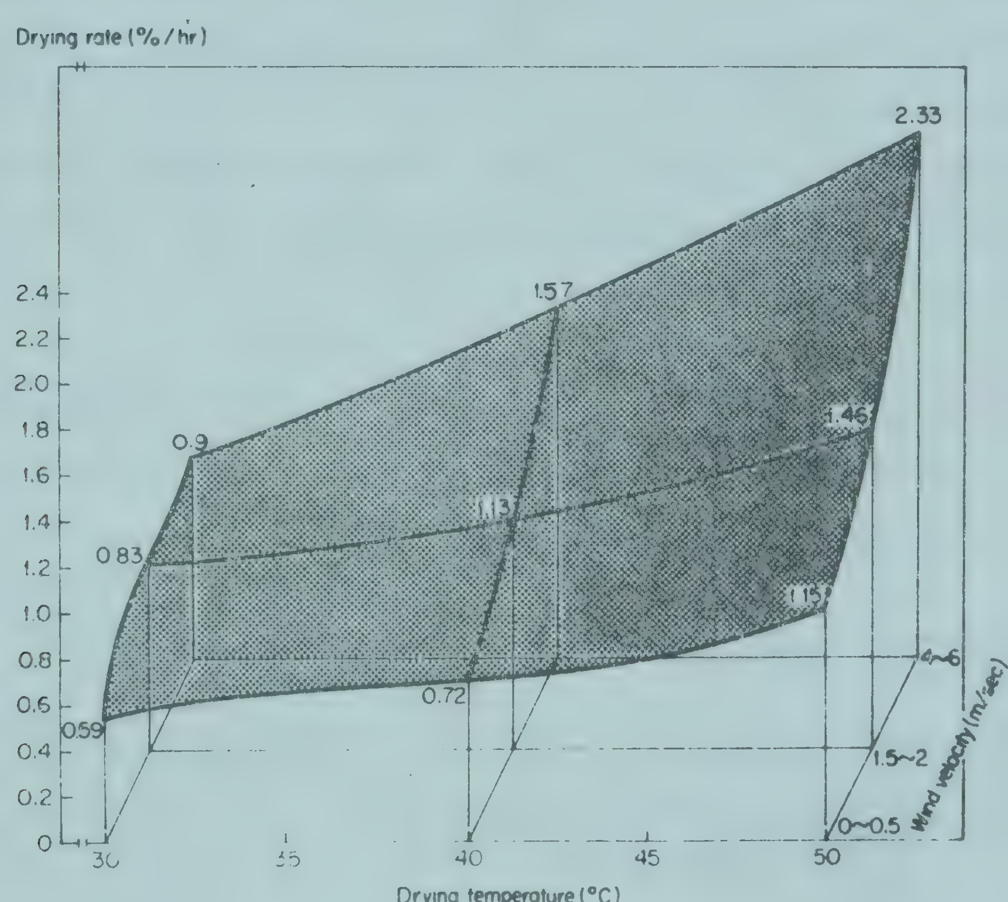
Figure 7 Effect of wind velocity on suction performances of vortex wind machine (VWM) and chimney (CH) from a close structure at ambient temperature (28.2^{o}C)



4. Drying system performance

A characteristic tri-dimensional curve (Figure 8) can be derived from observations of the effect of drying temperature and wind velocity on the drying rate of paddy. It will be observed that temperature does not significantly affect the drying rate at low velocities, although in general, the drying rate increases with an increase in temperature. The effect of wind velocity and temperature becomes increasingly important at high levels. A high drying rate, however is not always desirable as it may be deleterious to the drying material especially for paddy where thermal stress and moisture diffusivity are critical conditions affecting crack generation.

Figure 8 Drying rate of paddy in a warehouse dryer as affected by drying temperature and wind velocity



The drying rate paddy in the IRRI convection (warehouse) dryer is characterised by a simple exponential model with drying constants varying as a function of drying air temperature, initial moisture content and column thickness.

5. Summary and conclusion

The dryer is simple and low cost technology requiring minimum operational maintenance and adjustments.

The dryer can be constructed from locally available materials such as rice straw blocks, soil-ash bricks, nipa and the like.

It is most applicable for drying and storing different materials in one batch or in separate lots and maybe used by individual farmer, a group of farmers or a rice miller.

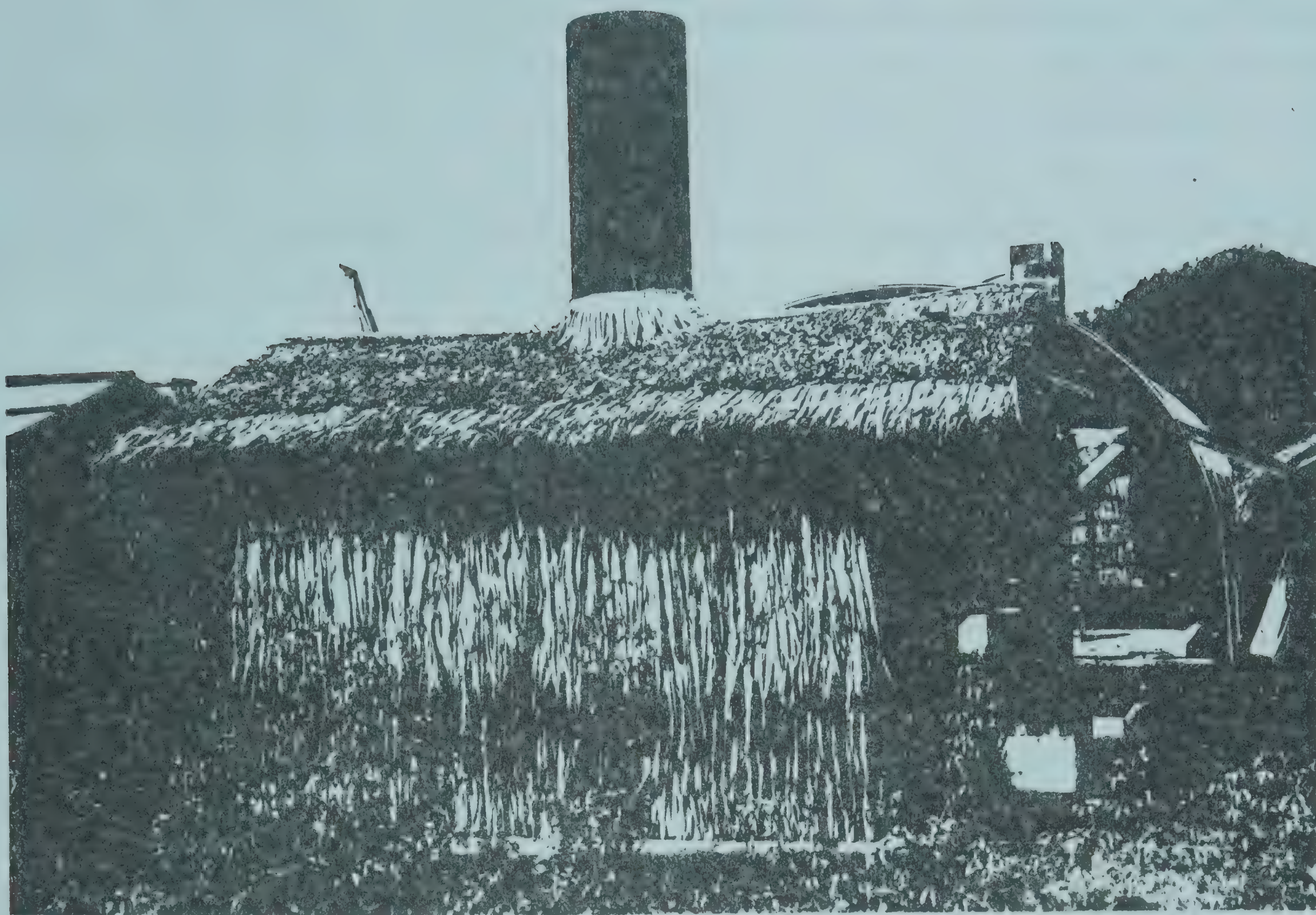
In general, the venting rate or airflow rate during drying has more influence on the drying efficiency of the system than any other management variables. The airflow rate control was found more critical than temperature control especially so that the drying operation is highly weather dependent.

An intensive aerodynamic analysis of airflow rate in the system is yet to be established.

The concept of this dryer design would obviously be acceptable as an intermediate technology but the context of application vary widely as weather conditions as well as the agronomic practices.

Appendix 1a

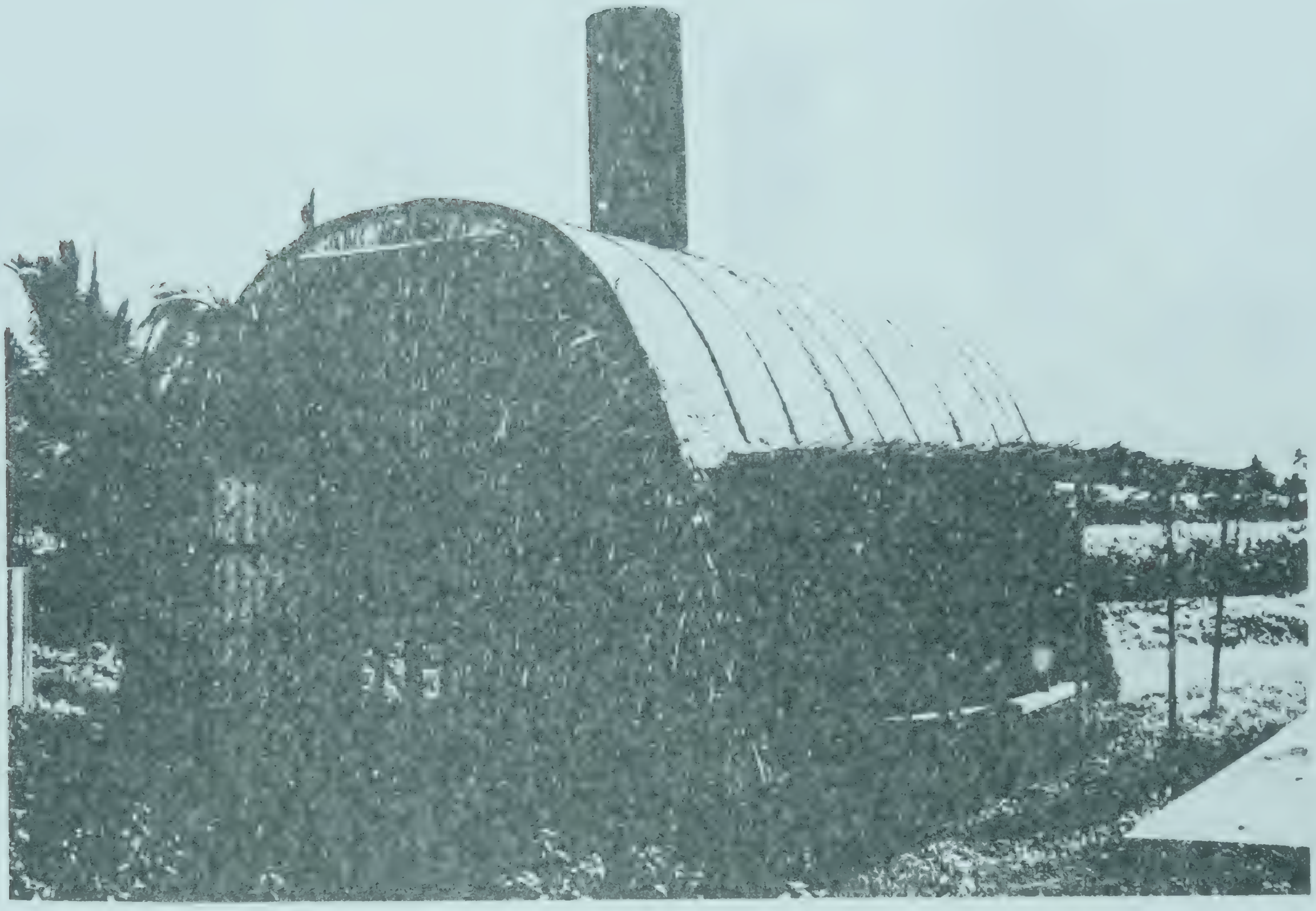
Warehouse dryer for individual farmer



The warehouse dryer houses equally spaced vertical trays for holding drying materials up to 1 t. It is provided with an indirect-fired heating system and a smokestack for air exhaust. A work space is also provided on both sides of the trays which can hold other drying materials. The side walls can be opened fully for better aeration. The floor area can also be used for pre-drying the incoming wet materials.

Appendix 1b

Warehouse dryer for village level operation
(Greenhouse type warehouse dryer)



The dryer combines sun-drying and artificial drying methods. The greenhouse type dryer has a clear plastic sheet roofing which intercepts solar radiation. The roof can also be made of woven bamboo mat plastered with asphalt. The main dryer has a capacity of 3 t and at the same time an additional 4 to 5 t can be stored on the other side.

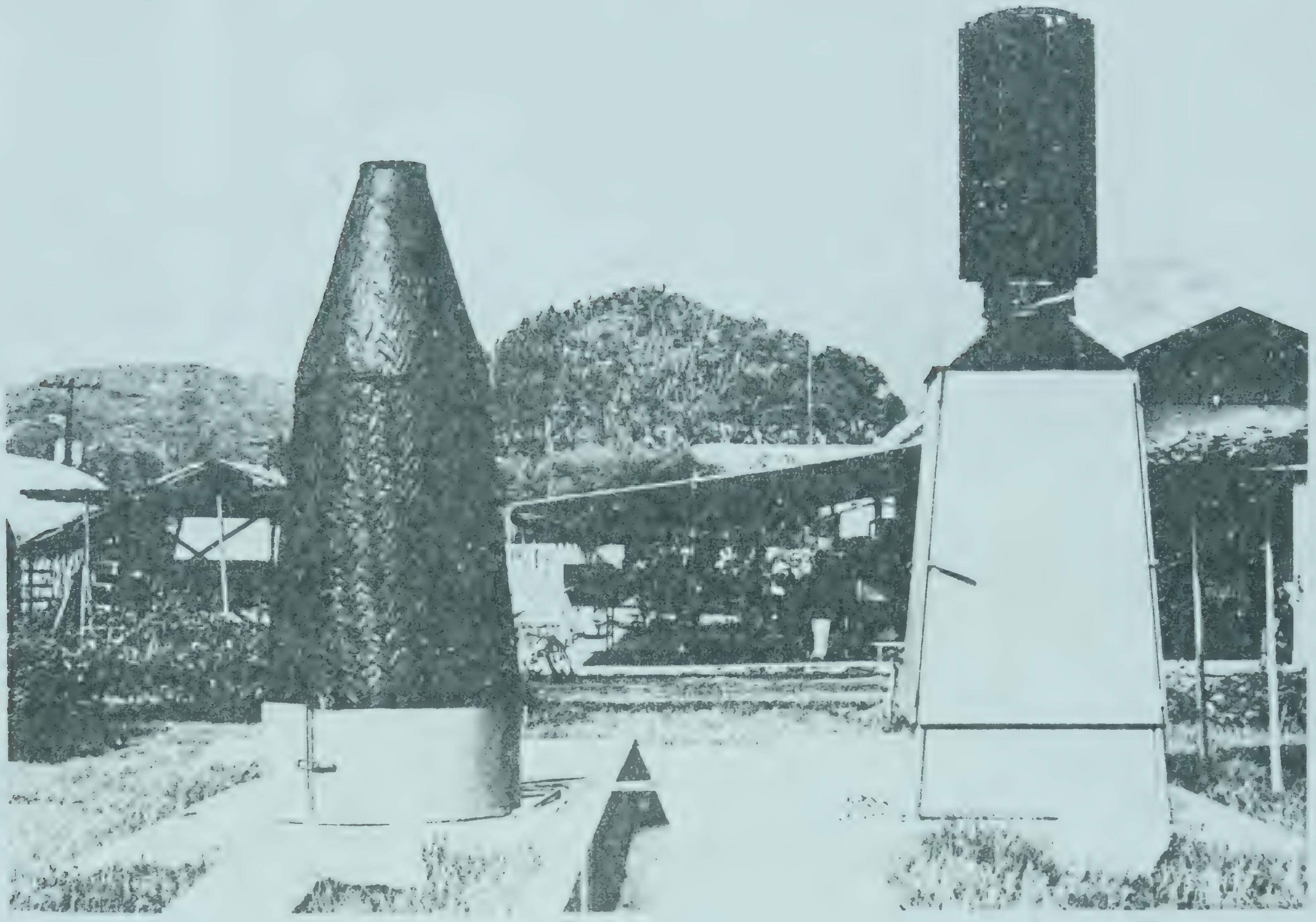
Appendix 1c

Warehouse dryer for medium-scale operation
("Winged" type warehouse dryer)

For a dryer capacity of up to 3 t, the "winged" type warehouse dryer is suitable. The extended corner walls direct wind from any direction into the warehouse thus, increasing the suction capacity of the vortex wind machine. The main dryer is heated directly using stoves fueled with rice hull charcoal briquette. The floor is also heated by an agrowaste-fueled furnace located at one end of the warehouse. The incoming high-moisture crops are spread on the floor for pre-drying before loading into the drying trays.

Appendix 2

Vortex fish dryer



The dryer is a direct-fired, specially designed structure for drying fish and other perishable products such as fruits and vegetables. Experiments on fish drying gave encouraging results. The drying capacity is 60 to 80 kg of fresh fish in 8 to 16 h. Rice hull charcoal briquettes are used as a source of heat with temperature controllable up to 60^{o}C.

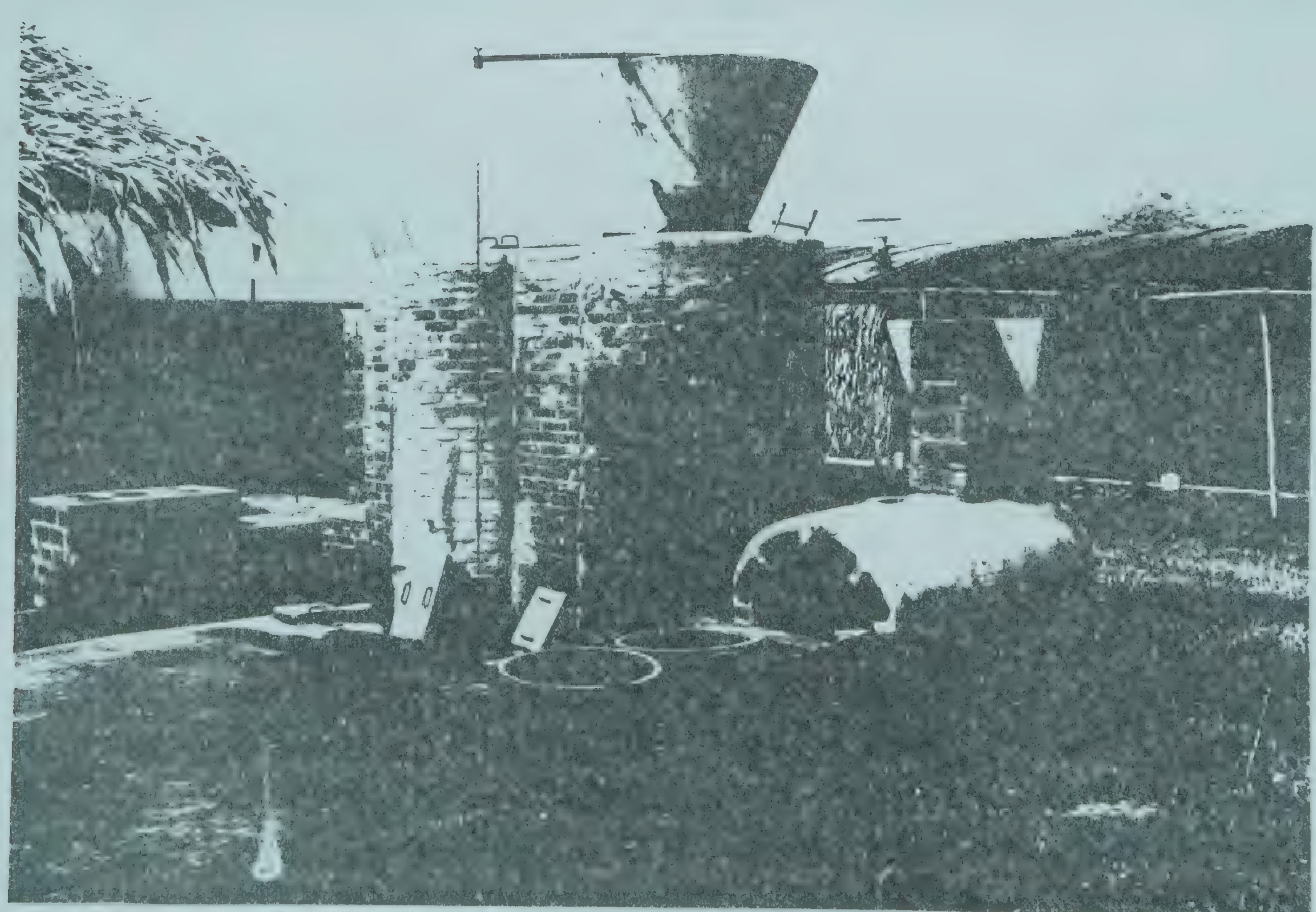
Appendix 3

Rice hull carbonizer and rice hull charcoal briquettes

In developing small capacity dryers, it is necessary to provide a direct-fired heating system in lieu of the expensive heat exchangers. The use of rice hull in the original form is not feasible because of contaminations that are likely to occur.

The proposed scheme is aimed to provide a clean source of heat from rice hull of direct-fired dryers. The concept involves development of a rice-hull carbonizer for the production of char. The volatile gases from carbonization is recovered, further burned in a center-tube furnace then used for drying or related applications. The char is collected and briquetted using soil as binder. The briquetted rice hull charcoal is a good source of heat for direct-fired dryers, for cooking and for other domestic uses.

The briquettes burn with pale orange clean flame generating temperature up to 800^{o}C for about an hour.



The rice hull carbonizer coupled to a center-tube furnace

Rice hull charcoal briquette and briquetting device

AGROWASTE FISH DRYERS

by

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1. Introduction

Traditional methods of sun-drying fish are subjected to many interruptions and difficulties during the rainy season resulting in substantial losses of fish or the production of poor quality dried products. Much of the latter are considered unfit for human consumption and are sold to fish meal producers at very low prices. Losses in fish and earnings is estimated to affect over 20 to 30% of the catch during the monsoon season, which can extend for up to 7 months per year in the Philippines.

Losses are primarily caused by microbial spoilage during rains or when the ambient relative humidity is very high. The drying rate is insufficient to reduce the moisture content of wet fish before the numbers of spoilage bacteria become significantly high. The blowfly population also increases during the rainy season. The flies lay eggs on the fish which quickly develop into larvae. The longer the flesh of the fish remains soft and moist the easier it is for blowfly larvae to gorge and damage the fish.

Frequently techniques for preserving or processing the catch are particularly a problem in remote coastal fishing communities or on smaller islands, where electricity for alternative methods of fish preservation is generally not available, and road links are too poor to market unchilled fish quickly.

A low cost artificial dryer that can be operated cheaply and constructed from locally available materials would offer an inexpensive alternative drying technique. The dryer would rely for fuel on the plentiful and under-utilised supply of agrowaste material such as rice hull and coconut husk that are abundant in most parts of the Philippines. Such dryers would help prevent losses of a valuable protein resource, ensuring good product quality, increase profitability thus benefiting fishermen, processors and ultimately the community.

Recognising the need for a low cost artificial drying technique to help fish processors through their recurrent annual plight, the Philippine-German Fisheries Project at the College of Fisheries, started in earnest in 1982 to develop agrowaste fish dryers. The intended target user were small scale fish processors, from these isolated fishing communities, with a daily processing

requirement of 1 to 3 "bañeras" or 40 to 120 kg of wet fish. Several models have since been designed and evaluated and these are discussed in this paper.

2. Background

The dryers developed at the College of Fisheries have all been vertical convection dryers with a drying chamber of approximately 2 cubic meters and suitable for drying about 40 to 120 kg of wet fish. The earlier designs utilised indirect heating methods where agrowaste materials are burned in a steel furnace, and, by heat exchange, the heat transferred to the air which passes over the fish to be dried. More recent models were heated by direct technique utilising charcoal as a smokeless fuel thus making more efficient use of the heat energy.

2.1 Low Cost Fish Dryer (LCF Dryer)

Constructed from hollow block (base), fibre board and timber (drying chamber) and G.I. sheet/steel (furnace, roof and chimney), the LCF dryer (Villadsen and Flores, 1982) is an indirect vertical convection dryer fueled by coconut husk, rice hull or firewood (Figure 1). For burning coconut husk and firewood a simple furnace arrangement was used with heat exchangers to heat the air. For rice hull with its finer structure and different burning characteristics, a more specialised furnace with a continuous feeding mechanism was utilised (Figure 2).

Hot air inside the drying chamber is said to travel horizontally over fish laid on wood framed, polyethylene mesh trays. The horizontal flow of air was brought about by allowing hot air from the heating compartment through a 20 cm wide space on the bottom left of the drying chamber, and three baffles at pre-arranged spacings introduced hot air at various heights and directing it across. The air exits into the dryer hood through a 20 cm wide space on the top left of the drying chamber (see Figure 1).

Splitted roundscad (Decapterus sp.) was reported to take 15 to 18 h to dry. Low air flows and inconsistent air temperatures inside the dryer resulted in the long drying times and variable dried products. Attempts to improve the air flow using a rotating ventilator or an inverted L-shaped hood were frustrated by low ambient wind velocities.

2.2 Steel dryer (Esbuscado, 1985)

Constructed entirely of steel, this dryer was designed to be easily dismantled and moved on to a new drying site if desired (Figure 3). The main structure of the dryer is made from G.I. steel plates (18 gauge) which are bolted together. The steel furnace is box-shaped with a central rectangular chimney which passes through the centre of the drying chamber.

Figure 1 Low cost fish dryer (longitudinal section)

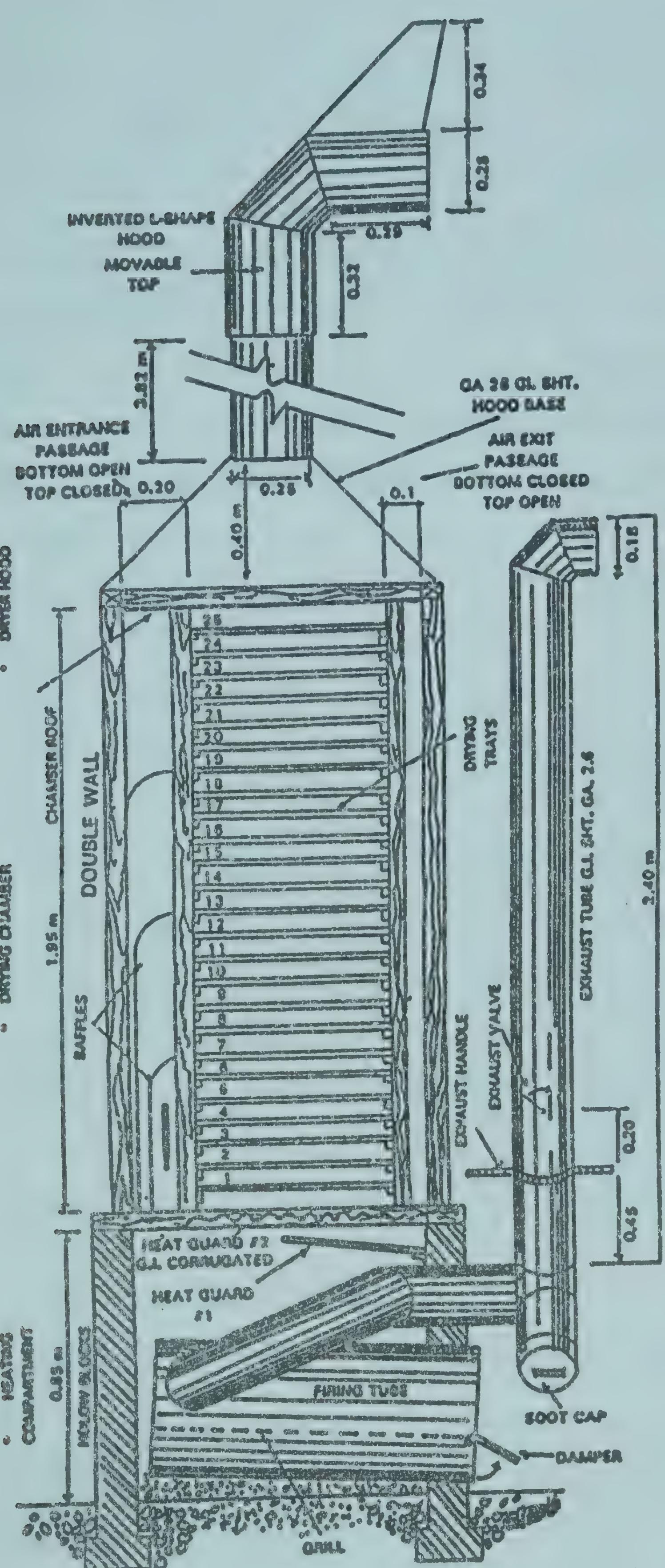
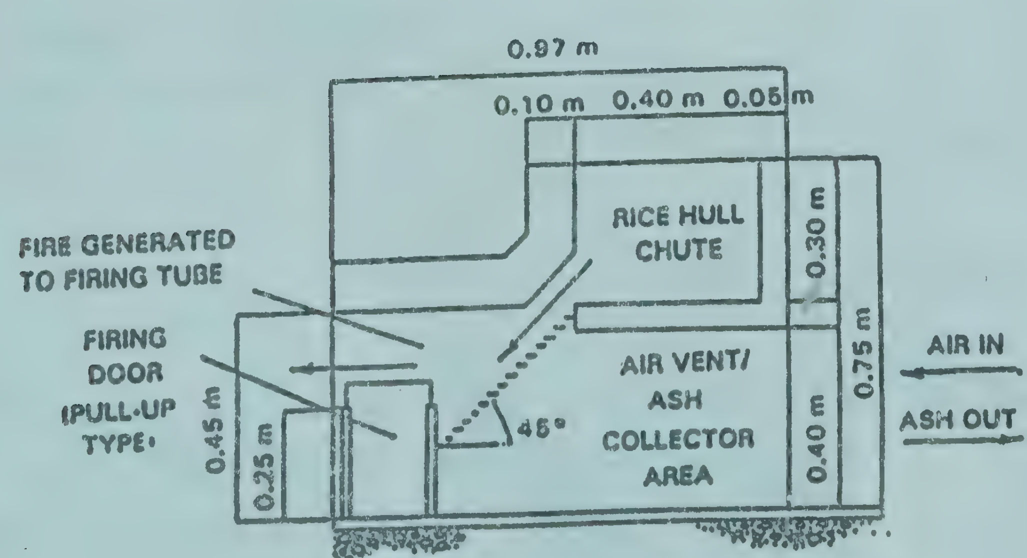
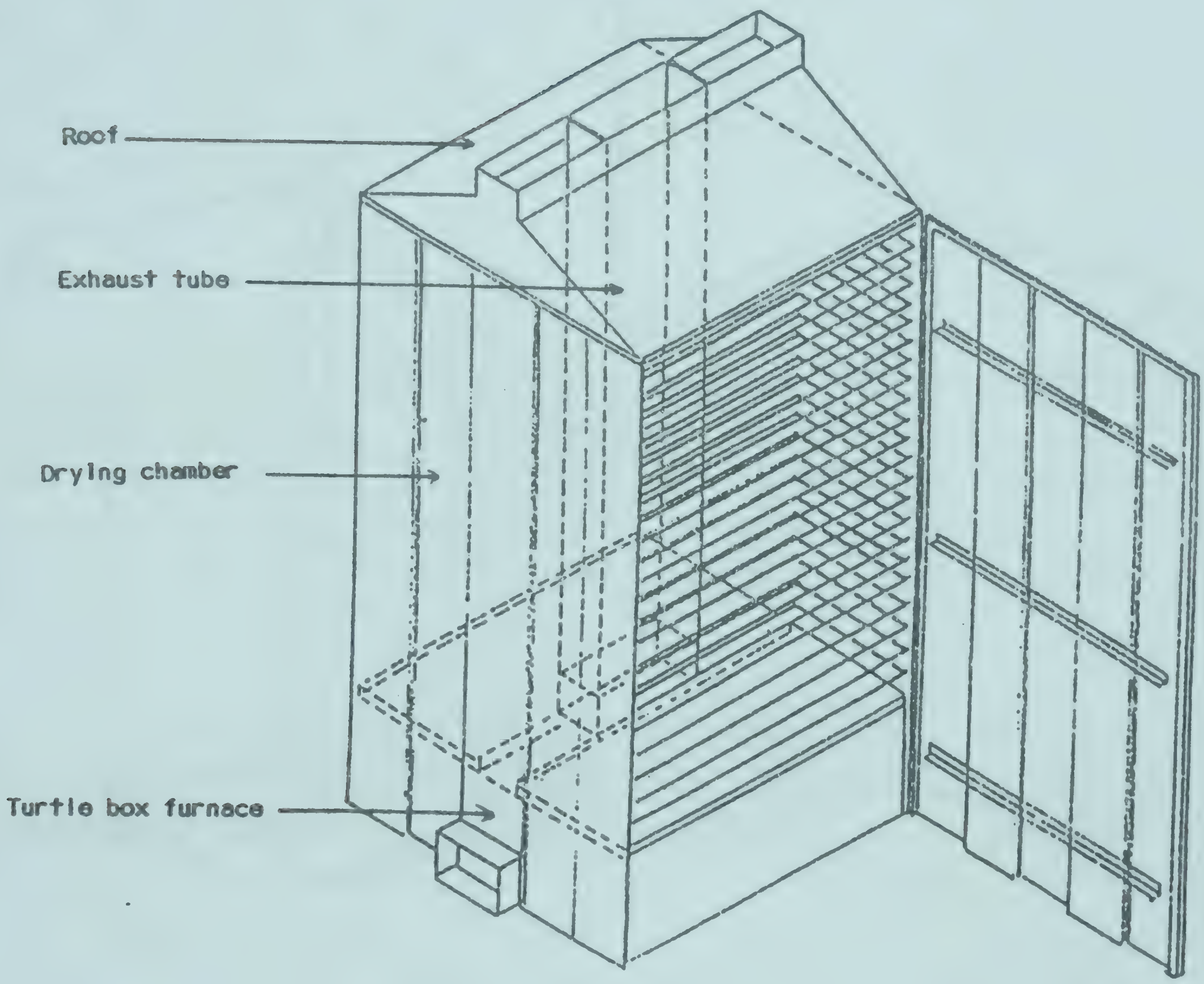


Figure 2 Rice hull furnace which is attached to firing tube (longitudinal section)



Coconut husk, firewood or charcoal can be used as fuel, but rice hull is unsuitable. Fish are placed on narrow steel wire trays which are positioned on either side of the central chimney. The dryer was found to dry squid within approximately 12 h, but had more difficulties in efficiently drying split fish (some fruit, coffee and cocoa were also successfully dried). The drying characteristics for fish result in approximately the lower 0.3 producing cooked dried fish, a central portion with wet fish where the relative humidity (RH) remains high, and an upper 0.3 where fish are again dry. However, these problems could be overcome by rotating trays during drying.

Figure 3 Steel dryer



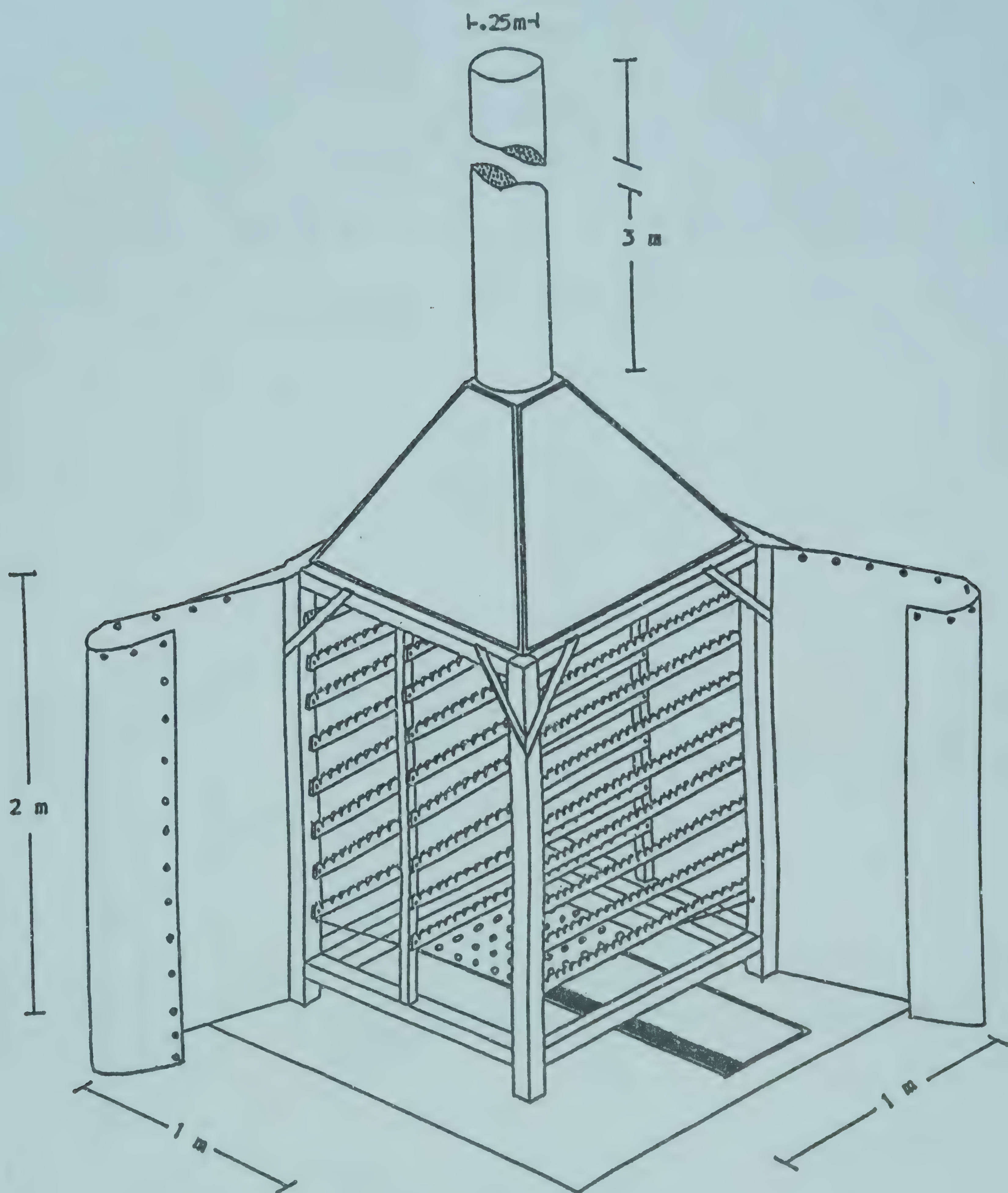
Low air velocity and excessive heat radiation for the central chimney were blamed for the dissappointing performance with fish. The high price of the dryer at ₱ 16,000 per unit, compared to subsequent models is also a drawback.

3. Recent designs of fish dryers

3.1 Canvas dryer

This design of direct convection dryer comprises a wooden frame and a simple angle iron and G.I. sheet roof and chimney. The wooden frame area is sealed with a canvas awning, thus enclosing the drying chamber (Figure 4).

Figure 4 Canvas Dryer (see text for details)



3.1.1 Drying Chamber

The internal dimension of the drying chamber is 2 m x 1 m x 1 m, with the corner supports constructed from 7 cm x 7 cm timber and front and back central supports 3.5 cm x 3.5 cm timber. On the right and left sides of the frame and on the central supports, knotched horizontal cross-pieces (4 cm x 1.5 cm) are bolted inside with 10 cm bolts and wing or butterfly nuts. These cross-pieces support the hanging fish for drying on bamboo sticks, and can quickly be adjusted to a variety of heights and spacings for different size fish by utilising the holes drilled 10 cm apart in the uprights. The knotches help space the sticks of fish at regular intervals.

When ready to proceed with drying a sheet of heavy duty plastic canvas 4.25 m x 2.1 m is wrapped tightly around the frame to seal the drying chamber. Brass grommets (12 mm) are fastened at 20 cm intervals along the top edge and along one of the side edges of the awning. One side of the canvas is tied with nylon string, utilising the grommets, to an upright of the dryer frame, and the canvas wrapped securely around the structure. The free edge overlaps the secured end of the canvas and is fastened by 25 mm wide, vertical strips of Velcro (magic - tape). The top edge of the canvas is kept in place by hooking the grommets onto short nails placed on the top face of the frame.

3.1.2 Roof and chimney

The four-sided roof is constructed with 25 mm angle iron frame and G.I. sheet. The sides of the roof are angled at 55^{0} to allow for unimpeded air flow. The rolled G.I. sheet chimney has a diameter of 25 cm and set at a length of 3 m. A simple "china hat" arrangement is placed 25 cm above the chimney outlet to stop rain from entering.

3.1.3 Heating method

Into a hollow block and cement pit 30 cm deep, 40 cm wide and 2 m long, below the drying chamber, a heat source of burning charcoal is centrally positioned. The smoke-free combustion gases mix with the surrounding air, and a 45 cm x 45 cm piece of G.I. sheet with 2 cm holes at intervals of 5 cm, placed approximately 20 cm above the heat source helps disperse the hot air evenly into the drying chamber.

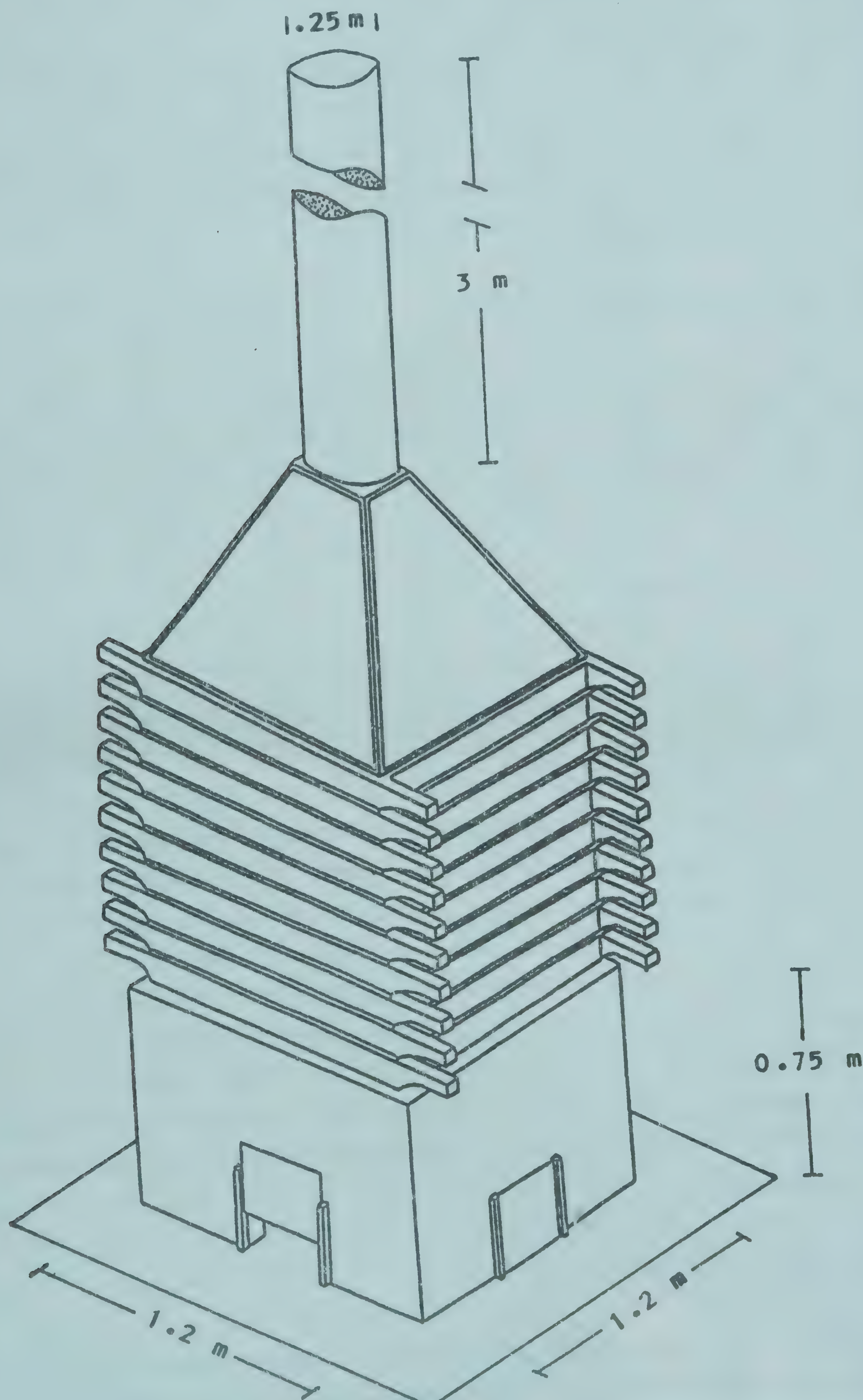
For direct heating, wood charcoal is burned in a small G.I. bucket (28 cm x 20 cm). The bucket has 12 mm holes punched at regular intervals (2.5 cm spacing) in the bottom and halfway up the sides. Two 20 cm pieces of 2.5 cm angle iron were bolted to the bottom to raise the bucket off the floor to allow good air supply to support combustion. A central column of chicken wire mesh of 5 cm diameter and 20 cm high is positioned in the centre of the bucket, and charcoal placed around the column. To start combustion one or two small pieces of burning charcoal are dropped down the middle of the mesh tube. The charcoal at the bottom will start to burn within 2 to 3 min. About 0.5 kg of charcoal maintains the required temperatures of between 40 to 50^{0}C in the drying chamber for about 50 min. A second similar bucket whose charcoal had been similarly ignited 5 min before the 50 min expired is exchanged with the dwindling first bucket at the set interval of time. The cycle continues until drying is completed.

3.2 Tray dryer

Drying of fish under good natural drying conditions is a cheap and effective method of producing dried products. It is only when the weather changes for the worse or at sunset does sun-drying come to a halt. The tray

dryer offers a system that helps continue drying under these conditions and adds versatility to the processors operation. The fish are placed to sun-dry as usual but on specially constructed tray. If rain threatens at any time, the trays are assembled on top of each other over a simple heating compartment,a roof and chimney is placed on top, and the drying continued by direct means with burning charcoal (Figure 5). If good sun-drying conditions return the trays can be relaid on traditional supports.

Figure 5 Tray Dryer (see text for details)



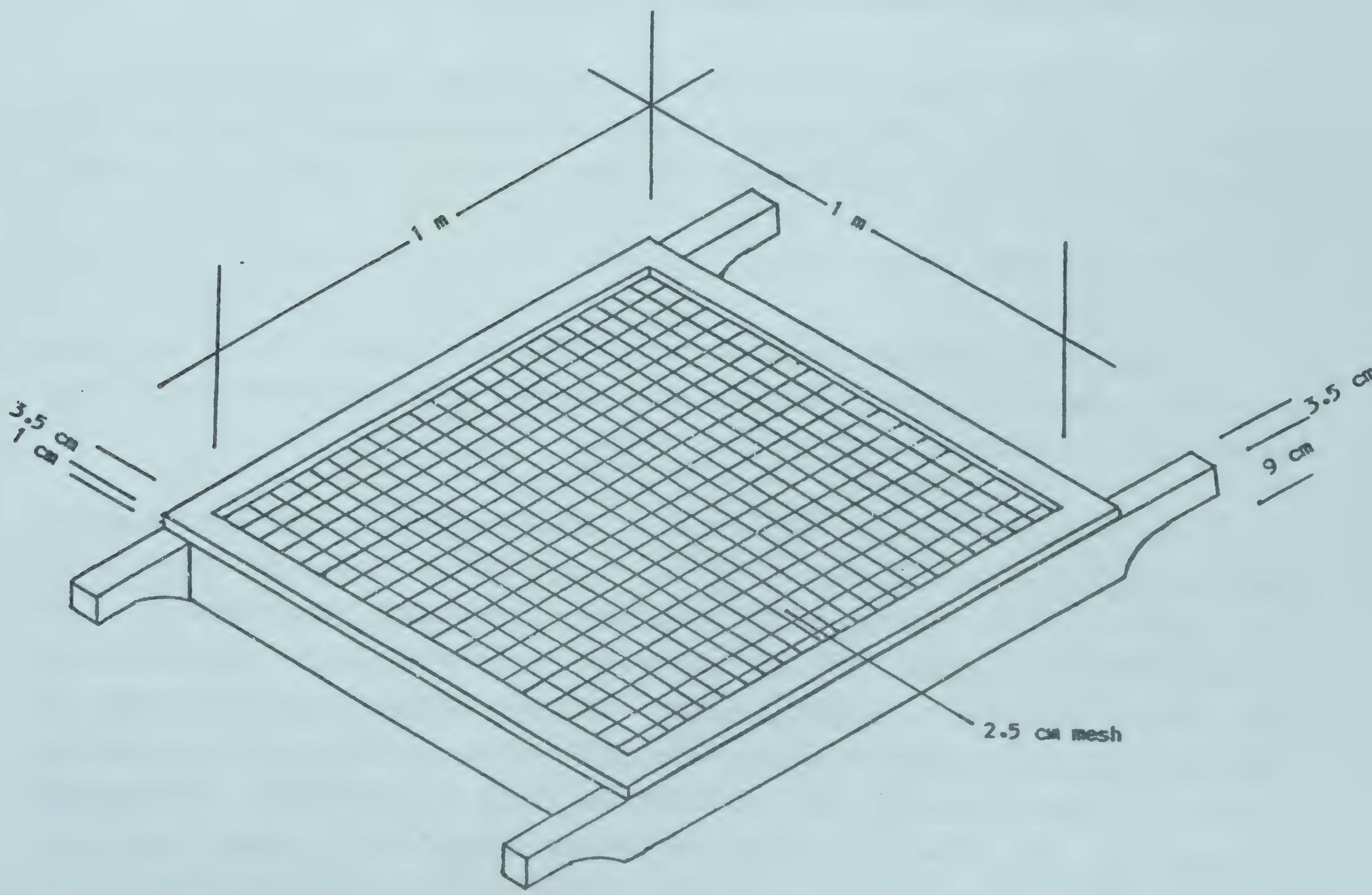
3.2.1 Heating compartment

The trays sit on a hollow block structure with an internal dimension of 1 m x 1 m x 0.75 m high. Openings of 30 cm x 30 cm, with adjustable sliding doors are centrally situated in each of the four sides. These openings permit control of the drying temperature by allowing cooler air to enter if needed. The top face of the structure must have a flat smooth surface to make a flush fit with the first tray. The same heating method as the canvas dryer is employed. The bucket of charcoal is placed in the centre of the heating compartment below a 45 cm x 45 cm G.I. sheet with 2 cm holes at intevals of 5 cm, hung about 20 cm above the bucket.

3.2.2 Drying trays

The trays have an internal dimension of 1 m x 1 m, with a depth of 10 cm and have a flush fit when placed on other trays or the heating kiln. The main frame, using 9 cm x 3.5 cm timber, is assembled leaving an extra 15 cm on each end of main length to act as handles. The mesh, either of 25 mm chicken wire or twine mesh, is tacked in place to cover the frame. The mesh is then sandwiched between 1 cm thick x 3.5 cm wide timber pieces (Figure 6).

Figure 6 Details of a tray from the Tray dryer



3.2.3 Roof and chimney

An identical roof and chimney used for the canvas dryer is secured to one of the tray frames. A flush fit with other trays when stacked is again important.

3.3 IRRI fish dryer

Collaborative effort between the Philippine-German Fisheries Project and the Department of Agricultural Engineering, International Rice Research Institute (IRRI) Los Baños, culminated in the IRRI fish dryer. The significant feature of IRRI's dryer is the Vortex Wind Machine (VWM). This is a stationary structure with vertical fins which sits on top of the drying chamber thus replacing the conventional chimney of some other dryers. The VWM harnesses wind energy that increases suction and therefore improves air flows in drying compartments.

The VWM sits on a drying chamber of approximately 1.5 cubic meter in volume, and fabricated of G.I. water pipe frame, angle iron and sheets of plywood. Fish hung on pieces of bamboo sticks are supported inside the dryer on simple bamboo frames. Heating is by direct convection by burning wood charcoal or charcoal briquettes prepared with rice hull charcoal (Jeon *et al.*, these proceedings).

4. Evaluating recent designs of agrowaste fish dryers

The 3 dryers designed and evaluated for drying performance, the IRRI, canvas and tray dryers were similarly treated for preparation of raw materials and monitoring of physical parameters for drying.

4.1 Fish preparation

Fish were purchased from the Navotas fish port complex making sure that they were completely fresh, and stored in insulated containers with ice. Fifty kg of fish were purchased for each drying run.

Only two species of fish were used in all drying procedures: threadfin bream (*Nemipterid* sp.) locally known as "bisugo", and roundscad (*Decapterus* sp.) locally called "galunggong". The threadfin bream were scaled, split through the back, gutted, gilled and washed thoroughly; while the roundscad were gilled, gutted and similarly washed. It was important that the isthmus, a structure between the opercular openings, was not cut during splitting because a stick is passed through the isthmus when fish are dried in the hanging position. If the isthmus was broken the sticks were pierced through the eyes.

Brining the fish in saturated brine lasted 1 h for threadfin bream and

2 h for roundscad. The fish were then washed in freshwater to remove surface brine.

Fish were either hanged on 1 cm x 50 cm lengths of bamboo or laid out on mesh trays.

4.2 Monitoring drying conditions

Four physical parameters were monitored throughout drying: temperatures, air velocities, relative humidities and weight changes of the drying fish.

The air temperature of the dryer were measured every 5 or 15 min, depending on the equipment used (Grant temperature and RH recorder and Ellab CTF-86-A1). Up to 7 probes were placed inside the dryer at various heights (top, middle and bottom) and positions (centre, corners and sides). A single probe was used to measure ambient temperatures.

Air velocities were measured with vane and thermal anemometer (Wilh. Lambecht Gmbh) at various points: vertical air flows inside the drying chamber; at the base of the chimney or VWM (suction point); and ambient wind velocity.

The Grant recorder was also used for measuring the relative humidity (RH), with two probes placed centrally at two different heights inside the drying area. Ambient RH (and temperature) was measured with a thermo-hygrograph.

Weight changes were monitored by simply removing pre-weighed duplicate batches of 3 fish weighing on a triple beam balance, and returning the samples quickly to the dryer. Weighings were conducted every 30 min for the first 2 h and then hourly. An alternative technique was used for the IRRI dryer, where weight losses were monitored continously with fish samples attached to electronic load cells inside the dryer.

4.3 Drying procedure

The fish drying run started when the burning charcoal was placed in the heating compartment of the dryers. The target temperature range of 40 to 50^{o}C (established from previous experiments in mechanical dryers) was adjusted by opening air vents or lifting the bottom edge of the canvas, when the temperature was too high, or closing all openings when the temperature was too low. The charcoal heat source was quickly exchanged with a fresh one when the old one was unable to sustain the required temperature. For 0.5 kg of wood charcoal, a combustion time of 40 to 50 min was allowed.

The drying was concluded when the fish monitored for weight loss had reached 50 to 55% of their weight at commencement of drying. The heat source was then removed and the dried product unloaded and stored.

Chemical analysis for moisture content (oven method), salt (Volhard method), water activity (using Lufft A_w-value Analyzer Model 5803) and fat (Bligh and Dyer method) (Appendix 1) were conducted on dried products.

5. Results and discussion

The performance of each dryer over a number of drying experiments are summarised in Tables 1 to 3. The RH values are not shown as in all cases it falls quickly to less than 50% soon after heating commences. This is sufficiently low to sustain drying. Typical drying curves for the three dryers are shown in Figure 7.

It is apparent that wide temperature fluctuations were experienced, particularly towards the beginning and end of the heating cycle with new and old burning charcoal. Close supervision of the heating cycle is therefore essential to minimise excessive temperature ranges. This is sometimes achieved, for example a temperature range of 40 to 50^{o}C was maintained in the canvas dryer for over 75% of a 14 h drying run, and over 90% of the time for 38 to 52^{o}C (i.e. $\pm$ 2^{o}C). It is more important not to let the temperature exceed 50 to 55^{o}C for any length of time during drying as cooking of the flesh is likely to take place.

Acceptable average temperature differences between top and bottom positions were evident for both the IRRI and canvas dryers. The tray dryer however suffered larger temperature fluctuations, and, additionally is more susceptible to cook the fish especially for the bottom 3 to 4 trays. Cooked fish are characterised by gaping and softening of tissue which results in a brittle dried product. The poor air velocity figures for this dryer contribute to the comparatively large temperature gradient and poor control over heat distribution.

Air flows in the other two dryers show considerable improvement particularly for the IRRI dryer with the VWM. This novel device has proved effective in increasing air velocities which is important in the earlier stages of drying to remove the moist air film that surround the wet fish, and to exhaust the increasingly humid air from the drying chamber. Good air velocity also helps disperse the heat more evenly throughout the chamber, minimising temperature gradients. As a result, the IRRI dryer show a shorter and more consistent drying performance.

Although the same roof and chimney arrangement was used for the canvas and tray dryers different air velocity profiles were measured. This is probably due to a better seal around the drying chambers with the canvas compared to the stacked trays, where small spaces between trays were difficult to eliminate. Additionally, a much smoother air passage with less interference is experienced with the fish in the hanging position, while fish in the laid position will hinder good air flows.

Table 1 Typical air temperature profiles inside the models of agrowaste fish dryers during fish drying

Dryer	**Typical Temperatures (^oC)**		
	Temperature ranges	Average temperature	Average temperature differences between top and bottom
IRRI dryer	30.2 - 86	47.8	3 - 4
Canvas dryer	34.3 - 68.1	45.1	3 - 5
Tray dryer	26.0 - 75.5	44.3	8 - 10

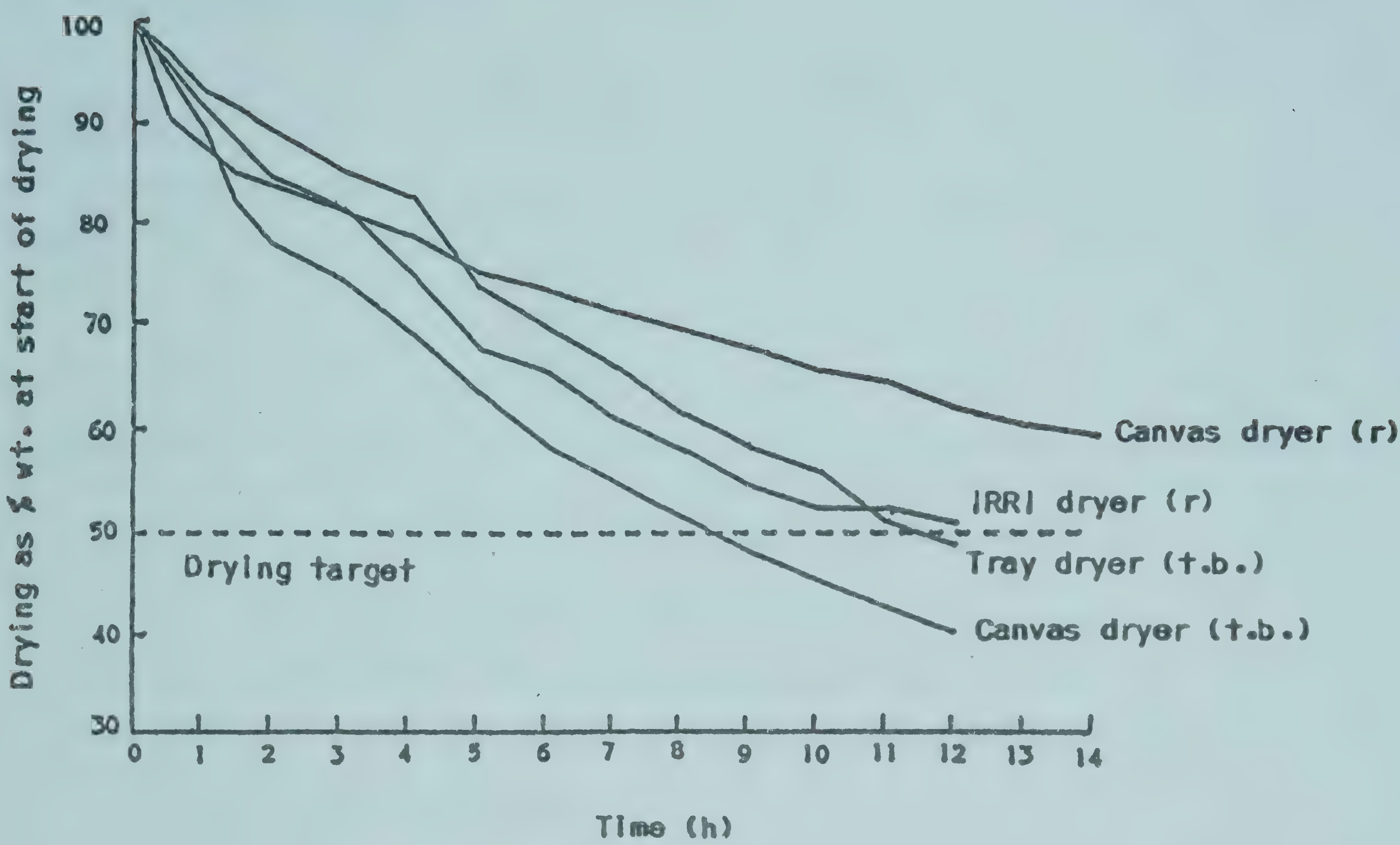
Table 2 Air velocity profiles inside three models of agrowaste fish dryers during drying

Dryer	**Typical Air Speed (m/s)**	
	Range	Average
IRRI dryer	0.1 - 1.8	0.38
Canvas dryer	0.02 - 0.34	0.17
Tray dryer	0.02 - 0.18	0.09

Table 3 Typical drying time for threadfin bream and roundscad in three models of agrowaste fish dryers

Dryer	Species	Position of fish	Duration of drying (h)
IRRI dryer	Threadfin bream	hanging	9 - 11
	Roundscad	hanging	9 - 10
Canvas dryer	Threadfin bream	hanging	9 - 12
	Roundscad	hanging	14
Tray dryer	Threadfin bream	lying	12 - 18

Figure 7 Drying curves for threadfin bream (t.b.) and roundscad (r) in various dryers



However, it must be remembered that the tray dryer was not designed primarily to turn wet fish to dry products, but help to continue with drying during short periods of inclemental weather or to complete drying in the evenings.

Minimal problems were encountered in utilising charcoal as a direct heat source for drying fish. In only one instance did taste panellists describe a slight "smokey" aroma and flavour on uncooked and cooked threadfin bream dried with wood charcoal. Occassionally, a thin layer of minute ash particles were found on dried products, which could easily be brushed off. It appears therefore that charcoal, whether from wood or rice hull charcoal briquettes can successfully be used for direct heating. An additional advantage is a set combustion period for specific weight or size of charcoal fuel. With indirect methods of heating, feeding of fuel into furnaces has to be monitored continuously.

The chemical analysis of commercial and experimental samples of dried threadfin bream are summarised in Table 4. These show reasonable similarities between the two groups of dried products. The water activity (A_w) figures indicate safe and extended storage capabilities of the products (if stored correctly or packaged properly). Salt concentration are a little low which suggest that brining time can be extended.

Table 4 Comparative chemical analysis of dried threadfin bream from commercial source and agrowaste dryers

Source	Moisture %	Salt %	A_w	Fat %
Iloilo	45.55	14.32	0.759	1.20
Bicol	43.06	14.32	0.740	1.01
Palawan	45.12	14.44	0.718	0.76
Cavite	47.58	14.42	0.769	0.70
IRRI dryer	39.08	13.95	0.737	0.82
Canvas dryer	44.05	12.13	0.76	0.67

The chemical analysis of roundscad (Table 5) show that drying this species whole is more difficult. This is also indicated in the drying curves (Figure 7).

Table 5 Chemical analysis of dried roundscad in the IRRI and Canvas dryer

Source	Moisture %	Salt %	A_w	Fat %
IRRI dryer	39.07 - 55.01	7.90 - 8.76	0.79 - 0.89	0.54 - 0.89
Canvas dryer	53.29	8.37	0.85	0.66

The A_ws for roundscad are too high for good preserved quality and salt levels are much too low. The fish develops a thick tough skin shortly after drying has started and this possibly acts as a barrier to further drying. Much longer brining is also needed to increase the salt concentration. Splitting the fish would also be better.

In conclusion, fish dryers have been designed and evaluated that can successfully dry split threadfin bream over a 9 to 12 h period. The IRRI dryer, with its superior air flows has shorter and more consistent drying times. All three dryers can be easilly manufactured from local materials and are cheap to build. Table 6 summarises the construction costs.

Table 6 Comparative prices of agrowaste fish dryers

Dryer	Price per unit ₱	Price per unit US$
IRRI dryer	< 4,000	< 200
Canvas dryer	3,000	150
Tray dryer	3,000	150
Steel dryer	16,000	800
LCF dryer	4,500 (1982)	225

(₱20 = US$ 1)

More emphasis is now needed on producing products to the requirements of fish processor from various regions of the Philippines and this can only be achieved by further experiments in the field working closely with fish processors.

6. References

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Villadsen, A. and Flores, F. Low cost, agrowaste dryer development. In Proceedings of the Workshop on the Production and Storage of Dried Fish, Lendang (Malaysia) 1982. James, D. (ed). Food and Agriculture Organization (FAO) Fish Rep. 279 (Suppl.)
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APPENDIX 1

Analytical procedures for cured fish

1. Introduction

Cured fish must be chemically analysed to assess their preserved status, help with quality grading and assist with setting up product standards. They are also essential for monitoring drying, testing storage conditions and effectiveness of different packaging.

Analysis considered important and routinely carried out at the Department of Fish Processing Technology are moisture, salt, water activity and fat. The following are the details of the methods used.

2. Determination of Moisture Content (using Oven method)

2.1 Principle

The moisture content of a material is determined by measuring the weight difference between the fresh material and the material weighed to a constant weight, in a hot oven by evaporation of water.

2.2 Apparatus

Analytical balance
Drying oven
Dessicator
Nickel or porcelain dishes
Tongs

2.3 Determination

Place a labelled nickel or a porcelain dish in the drying oven at 105°C, for at least 5 h. (Preferably overnight)

Remove the dish from the oven and cool it in a dessicator for 20 min.

Weigh the dish accurately (to 4 decimal places), put 2 to 5 g of the

sample into dish and weigh accurately again.

Replace the nickel or porcelain dish with the sample into the drying oven for 20 to 24 h. After this time, remove the dish, cool it immediately in a dessicator (20 min) and weigh accurately.

Carry out determination in duplicate.

2.4 Calculation

Weight loss is assumed to be entirely due to evaporation of water.

$$\% \text{ Moisture} = \% \text{ weight loss} = \frac{\text{Weight of moisture lost}}{\text{Weight of sample}} \times 100$$

3. Determination of Salt (Modified Volhard method)

3.1 Principle

Salt is determined as chloride ion by first precipitating it by an excess of known amount of silver nitrate. The insoluble silver chloride is removed by filtration while the excess silver ions are titrated with potassium thiocyanate with ferric indicator. A red brown colour develops a soon as all the silver ions are precipitated.

$$Ag^+ + Cl^- \longrightarrow AgCl\downarrow + \text{excess of } Ag^+$$

$$\text{excess } Ag^+ + SCN^- \longrightarrow AgSCN\downarrow$$

$$\text{slight excess } SCN^- + \underset{\text{(Ferric indicator)}}{Fe^{+++}} \longrightarrow \underset{\text{red brown colour}}{FeSCN^{++}}$$

3.2 Apparatus

Analytical balance
Weighing boats
Hot plate
Finger condensers
Burette, 50 ml
Pipettes 25 ml, 20 ml, 5 ml and 1 ml
Conical flasks, 250 ml

Volumetric flasks, 1 litre, 500 ml and 100 ml
Filter funnel (10 cm diameter)
Filter paper (Whatman 540)

3.3 Reagents

Concentrated nitric acid, HNO_3.

Silver nitrate, $AgNO_3$, standardised solution, 0.1 N.

- Dissolve 17 g analytical grade silver nitrate in distilled water and dilute to 1 litre in a volumetric flask. Protect the solution from light. Standardise against 0.1 N sodium chloride solution (see later).

Potassium thiocyanate, KSCN, standardised solution 0.1 N.

- Weigh out 9.74 g KSCN dissolve in distilled water and dilute to 1 litre in a volumetric flask. Standardise against standard 0.1 N $AgNO_3$ (see later).

Ferric indicator, $FeNH_4(SO_4)_2$, 10%

- Dissolve 10 g of $FeNH_4(SO_4)_2.12H_2O$ in distilled water and make up to 100 ml.

3.4 Standardizing solutions

3.4.1 0.1 N $AgNO_3$

Weigh out 2.922 g analytical grade sodium chloride (NaCl), dissolve in distilled water and dilute to 500 ml in a volumetric flask. Pipette 25 ml of this solution into a 250 ml conical flask and add 1 ml of indicator solution (a 5% solution of potassium chromate (K_2CrO_4) in water). Titrate with 0.1 N silver nitrate solution swirling the liquid constantly until the first permanent colour deviation from the pure yellow of the suspension is obtained.

Calculation:

$$\frac{g \times 25 \times 1000}{58.45 \times 500 \times ml} = \text{normality}$$

where g = weight of NaCl in 500 ml solution

58.45 = mol. wt. of NaCl

ml = ml $AgNO_3$ used in titration

3.4.2 0.1 N KSCN

Pipette 20 ml of the standardised 0.1 N silver nitrate solution into a 250 ml conical flask, add 5 ml 10% ferric indicator, and titrate with the KSCN solution. The end point is the first faint red colouration. Calculate f for the final calculation (see end):

$$f = \frac{\text{ml } AgNO_3}{\text{ml } KSCN}$$

3.5 Determination

Chop and mix the flesh of the fish thoroughly. For duplicate samples weigh about 2 g (to 2 decimal places) of the material into a 250 ml conical flask. Add standardised silver nitrate solution according to the following table.

If concentration of NaCl approximates 6 to 8%, add 30 ml of 0.1 N $AgNO_3$

8 to 9,	35
10 to 11,	40
11 to 12.5,	45
12.5 to 14,	50

Add 12 to 15 ml concentrated nitric acid to the sample, place a finger condenser with water running through, in the neck of the flask, and heat gently on the hot plate until the sample is completely dissolved. Only a white precipitate of silver chloride should remain. Cool the flask and filter the liquid into another 250 ml conical flask. Rinse the first flask and the filter 3 times with distilled water; collect the washing in the second flask.

Add 5 ml 10% ferric indicator solution and titrate with 0.1N potassium thiocyanate until the colour of the solution changes a faint red brown.

3.6 Calculation

$$\frac{(ml_a - ml_t \times f)n \times 58.45 \times 100}{1000 \times g} = \% \text{ salt}$$

where ml_a = ml $AgNO_3$ added to the sample

ml_t = ml KSCN used in titration

n = normality of $AgNO_3$ solution

58.45 = mol. wt. of sodium chloride

g = weight of sample

f = factor for standardised KSCN

4. Determination of Water Activity (A_w) (Using Lufft A_w-value Analyzer Model 5803)

4.1 Principle

The water activity (A_w) is a measure of the water available to support microbial growth in a given food product. This is different to the total water content of the food because a proportion of it is bound by water soluble salts, proteins and carbohydrates. The A_w is a useful indicator of the stability of foods to all types of microorganisms.

4.2 Apparatus

A_w meters (Lufft A_w-value analyzer model 5803) - 3 per sample

4.3 Calibration

1. Clean lower A_w chambers with detergent and tap water.

2. Rinse with distilled water.

3. Dry thoroughly.

4. Calibrate the sensor head first, to determine the A_w-value by placing 4 sheets of the supplied special paper in the sample container, and moisten with the saturated barium chloride solution. (Note: shake the barium chloride solution well immediately before use)

5. Secure the sensor head by a special lock and let it stand for 3 h in an environment of constant temperature e.g. air conditioned room (Insulate the instruments if necessary).

6. Calibrate the sensor head by adjusting the A_w-value to 0.88 at 30^oC by using the supplied wrench to the adjustment screw (see table on container for different ambient temperatures).

4.4 A_w determination

1. Chop up sample coarsely and place in the lower sample container. Fill up halfway to the gasket ring. Carry out procedure in triplicate.

2. Allow to equilibrate at constant temperature for 12 h. Take readings.

   Note: In this method, you get three A_w readings of the sample at the same time, but three sensor heads should be calibrated before starting the determination. Re-calibrate sensor head after using it twice.

5. Determination of Oil Content (Bligh and Dyer method)

5.1 Principle

The material is homogenised in a mixture of chloroform and methanol in such proportion that a miscible system is formed with the water of the sample. Dilution with chloroform and water separates the homogenate into layers. The lipids dissolve in the chloroform layer while the non-lipids are contained in the methanol layer. Chloroform is evaporated from the extract leaving the oil content of the material to be weighed.

5.2 Apparatus

Tissue macerator/Homogeniser
Centrifuge
Centrifuge tubes
Oven
Measuring cylinders 20, 50 ml
Pipettes 5 ml, 10 ml
Filter funnel 10 cm
Beaker 50 ml

Conical flask 100 ml
Pasteur pipette

5.3 Reagents

Chloroform analytical grade
Methanol analytical grade

5.4 Determination

The weight of sample used for the determination depends on the likely oil content of the test material. The following table should be followed for accurate weight of material and volume of distilled water (if required) to be placed in the macerator flask.

	Wt. of material to be added to macerator flask (g)	Distilled water added (ml)
Lean fish, less than 5% oil	15	0
Fish with higher oil content, more than 5% oil	10	5
Presscake (not dried)	10	5
Fish meal	5	12

Fifteen ml chloroform and 30 ml methanol are added and the mixture macerated at full speed for 2 min. Another 15 ml chloroform is added and the mixture macerated for a further 30 sec at full speed. Finally, 15 ml distilled water is added and the sample again macerated for 30 sec.

The contents of the macerator flask is poured into the centrifuge bottle, and centrifuged for 15 min at 3,000 rpm.

After centrifuging, the water phase at the top of the bottle is removed using a pasteur pipette. The chloroform phase is poured through a filter, previously moistened with chloroform, into a 100 ml flask, which is then corked.

Ten ml extract is accurately pipetted into a small labelled beaker which has been dried in the oven, cooled and weighed. The chloroform is evaporated by heating gently on hot plate in a fume cupboard, and the sample is

finally dried in a drying oven for at least 2 h at 105^{o}C, cooled in a dessicator and weighed accurately. Carry out procedure in duplicate.

5.5 Calculation

$$\% f = \frac{(\text{wt. flask + fat}) - \text{wt. flask} \times 3}{\text{wt. sample}} \times 100$$

MYCOTOXINS IN SEAFOODS

by

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Introduction

Mycotoxins are toxic substances produced by fungi. They differ from bacterial toxins in that most are low molecular weight compounds and they do not initiate antibody-formation (non-antigenic). Mycotoxicosis is the diseased state produced by ingestion or inhalation of mycotoxins. Circumstantial evidence exists from mycotoxins being carcinogenic in man, as well as causing kidney disfunction and liver damage. It is difficult to establish that mycotoxins actually cause such disease in man because controlled experiments have not been carried out. In one study aflatoxin B_1 was detected in specimens of urine, liver, kidney and brain of Thai children who had died from brain inflammation and fatty degeneration of liver (Shank *et al.*, 1971). Mannon and Johnson (1985) reported that a striking correlation exists between the more aflatoxin contaminated food people eat and the incidence of primary liver cancer particularly in Asia and Africa. The incidence of maize contamination by aflatoxin ranged from 35, 40 and 97% in Thailand, Uganda and the Philippines respectively (Stoloff, 1977). Feeding trials with animals have established mycotoxins as potent hepatoxins, carcinogens, teratogens and mutagens (Bullerman, 1981a).

Table 1 lists some of the moulds which are of importance in foods because of potential mycotoxin production. The most well known is aflatoxin, produced by *Aspergillus flavus* and *Aspergillus parasiticus*, which first came to prominence when over 100,000 turkeys died after feeding with peanut meal contaminated by *Aspergillus flavus* (Sargeant *et al.*, 1961). Food microbiologists classify fungi into two groups - field and storage fungi. Field fungi are those invading crops prior to harvesting and require moisture levels for growth. Storage fungi are characterised by their low moisture requirement and cause spoilage after harvesting. The most important toxinogenic storage fungi are *Aspergillus* and *Penicillium* while *Fusarium* can be classified in either group.

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Table 1 Some mycotoxins of public health significance

Mycotoxins	Mould Species
Alfatoxin	*Aspergillus flavus*
	Aspergillus parasiticus
Citrinin	*Penicillium citrinum*
Luteoskyrin	*Pencillium islandicum*
Ochratoxins	*Aspergillus ochraceus*
	Penicillium viridicatum
Zearalenone	*Fusarium graminearum*
Tenuazonic acid	*Alternaria* sp.
Stachybotrytoxin	*Stachybotrys atra*
Ergotoxins	*Claviceps purpurea*

It is evident on reviewing published work that mycotoxins are of prime importance in dried agricultural products such as cereal grains, peanuts, beans and spices (Jarvis, 1976; Christensen *et al*., 1967; Banwart, 1979). Toxinogenic moulds have also been isolated from meat (Bullerman *et al*., 1979; Ciegler, 1975) and dairy products (Bullerman, 1981b). Few data are available on the occurrence of mycotoxins in seafoods when compared to the extensive reports on other food commodities.

Occurrence of toxinogenic fungi in fishery products

It is very unlikely that mycotoxins will be produced in fresh fish which is correctly stored in ice because of competitive growth of psychrophilic and psychrotropic bacteria and low temperature storage. Similarly mycotoxins should not present problems when good quality fresh fish are canned. Fungi constitute only a small portion of the microbial population of fresh fish and are only a problem in spoilage of fishery products when bacterial numbers have been restricted in some manner. Thus, a potential for mycotoxin contamination exists in dried, salted and smoked fish, fish meal, fish protein concentrate and fermented fishery products. Wu and Salunkhe (1978) isolated 114 fungi from dried shrimp of which 27 were capable of producing mycotoxins. *Penicillium* and *Aspergillus* spp. were the most frequently isolated. They comprised 94% of the total fungal isolates. Next in order of frequency of occurrences were *Rhizopus*, *Clodosporium*, *Alternaria* and *Trichotheceum*. Sixteen of the *Aspergillus* and nine of the *Pencillium* cultures were toxic to chick embryos. Table 2 shows the isolates which were toxic. Three of the *A. flavus* isolates produced aflatoxin under laboratory conditions, however aflatoxin was not isolated from the original dried shrimps samples.

Table 2 Fungi isolated from dried shrimp found to be toxic to chicken embryos

Aspergillus	Penicillium	Others
A. flavus	*P. expansum*	*Alternaria* spp.
A. amstelodami	*P. viridicatum*	*Cladosporium* spp.
A. ruber	*P. cyclopium*	
A. repens	*P. notatum*	
A. chevaliere		
A. fumugatus		

(Wu and Salunkhe, 1978)

Okonkwo and Nwokolo (1978) found dangerously high levels (400 to 800 ug/kg) of aflatoxin in improperly stored dried fish in Nigeria. Uraih and Ogbadu (1982) reported the production of aflatoxin B_1 and G_1 when dried and smoked tilapia were inoculated with *A. flavus*. The potentially toxic moulds *A. rubber*, *A. flavus* and *A. ochraceus* were isolated from dried and salted tropical fish by Philipps and Wallbridge (1977). In the Philippines, Trinidad *et al.* (1983) found *Aspergillus flavus* in brine used for fish smoking. In some commercial fish smoking plants brines are re-used for one year or longer and products are heavily contaminated with xerophilic fungi. Aflatoxin (5 ug/kg) was found in 5% of dried fish and shrimp samples in market foods from Thailand (Shank *et al.*, 1972). The same authors also reported detection of aflatoxin in fermented shrimp paste. Reports from the FAO (Anon, 1979a,b) indicated that 5% of dried shrimp samples from Thai exports contained aflatoxins at a concentration of 166 ng/g and those from Indonesia at 5 ng/g. Sim *et al.* (1985) screened dried shrimp and shrimp paste for toxinogenic moulds and found aflatoxin producing *A. flavus* present in the dried shrimp only. Toxins were not isolated from these foods but they were visually mouldy with mould counts (2×10^3 to 2×10^8 colonies/g). Bulato-Jayme *et al.* (1981) found aflatoxins present in market samples of dried and smoked fish at mean levels of 3.8 ng/g and the samples were visually non-mouldy.

Although there are no reported incidences of consumers being poisoned by mycotoxins in fishery products there is a definite risk to human health considering how fish are traditionally processed. Delays in drying fish during the rainy season, the use of heavily contaminated brines and low standards of hygiene all contribute to contamination by toxinogenic moulds. A common practice for fish vendors is to wash or scrape visual mould colonies off dried fish and to re-dry the products. This could lead to serious health risks for the consumer if toxic species are present as mycotoxins and are diffused into the growth medium by some moulds. Traditionally processed seafoods are the staple diet in many parts of Southeast Asia and even if only low levels of mycotoxins are present, consumption over the long term may lead to chronic health problems. Sun-drying spoiled or semi-spoiled fish for fish meal production may also cause serious problems when used as animal feed.

Control of mycotoxin production in fishery products

The control of mycotoxin production in fishery products is very different from controlling bacterial toxin formation and contamination. The basic reasons are that moulds require different growth conditions which includes growth over a wider pH range and at lower water activity levels. Generally moulds do not tolerate the same extremes of temperature as thermophilic and psychrophilic bacteria. All toxinogenic moulds are aerobic which means that oxygen is required for growth and toxin production.

Formation of mycotoxins in seafoods can be controlled by controlling environmental growth conditions. The most practical approach to control is prevention of fungal growth, although the presence of a mycotoxic fungus in seafoods does not necessarily indicate the presence of mycotoxins.

The rapid reduction of the water activity (a_w) is the most important factor in controlling mould contamination of fishery products. During storage the relative humidity of the environment must also be controlled in order to avoid re-absorption of moisture. In general the minimum a_w for toxin production is higher than the minimum a_w for growth. Table 3 shows the a_w for growth and toxin production by various moulds. However, it is important to stress that other parameters such as temperature, substrate and mould strain will affect toxin production. Bullerman *et al*. (1984) reports that aflatoxins can be produced at conditions of a_w and temperature that are near the minima for growth, whereas patulin, penicillin acid and ochratoxin are produced within a narrower growth range. The minimum a_w reported for mycotoxin production is 0.81 (Troller, 1980) and provided fishery products are maintained below this level, mycotoxicosis is unlikely to occur.

Table 3 Minimum a_w growth and toxin production

Species	Toxin	Minimal a_w Growth	Toxin Production
Aspergillus flavus	Aflatoxin	0.78	0.83 - 0.87
Aspergillus parasiticus	Aflatoxin	0.82	0.87
Penicillium viridicatum	Ochratoxin	0.83	0.83 - 0.86
Penicillium expansum	Patulin	0.83	
		0.85	0.99

(adopted from Beuchat, 1981)

Temperature control is a standard means of seafoods preservation. Generally fishery products which are most likely to support toxinogenic mould growth, such as dried-salted, smoked-dried, fermented fish and fish meal, are not stored at low temperature but at ambient tropical temperatures (25 to 30°C) which are optimal for aflatoxin production. Most studies show that aflatoxins

will not be produced below 8 to 10 ^{o}C (Bullerman et al., 1984). However, some moulds belonging to the genus Penicillium are capable of producing mycotoxins at temperatures as low as -2 to 10^{o}C, (Bullerman, 1981a).

The control of pH alone is of little value in the control of fungal growth in food. Fermented fishery products rely on the combined action of pH, due to lactic acid production by lactic acid bacteria and the addition of salt for preservation. The overall ability of lactic fermented fishery products to support growth of toxinogenic moulds and toxin production has yet to be investigated. The use of weak acids as anti-mycotic agents in foods is well documented (Banwart, 1979). Sorbic, propionic, benzoic and acetic acids and their derivations have potential use as anti-fungal agents in the production of dried and smoked fish. Bersamin et al. (1959) found that sorbic acid was effective in inhibiting mould growth on dried fish at concentrations of 0.5 to 1.0%.

While reports of fishery products supporting growth of mycotoxins are very few, the occurrence of mycotoxins in plant and animal products is well documented (Bullerman et al., 1979; Bullerman et al., 1984; Bullerman, 1981a; Watson, 1984; Ciegler, 1975; Javis, 1976). One of the few reports showed that wood smoke delayed aflatoxin production. Table 4 shows how aflatoxin production was related to moisture content in smoked and dried tilapia which were inoculated with A. flavus.

Table 4 Effect of moisture content on smoked and dried tilapia in relation to aflatoxin production incubated for 6 days at 27^{o}C

Moisture Content %	Aflatoxin (ug/g) dried fish		Aflatoxin (ug/g) smoked fish	
	$_1$	G_1	B_1	G_1
5	ND	ND	ND	ND
10	1.2	0.8	ND	ND
15	2.1	1.5	ND	ND
20	3.0	2.2	ND	ND
25	3.5	2.6	ND	ND
30	3.6	2.6	0.9	0.6
50	8.3	6.9	8.0	7.2

ND - NOT DETECTED (from Uraih and Ogbada, 1982)

Persistence of mycotoxins in fishery products

The common practice of removing visual mould growth from dried or smoked fish by washing will not guarantee the removal of mycotoxins if they have been produced. Mycotoxins are heat stable. Normal cooking temperatures of fish are not likely to reduce the aflatoxin content and thermal processing

of canned foods does not eliminate all mycotoxins. Further study on the stability of mycotoxins in seafoods is required to fully assess the situation.

Limits and regulations on mycotoxins

Regulations specifically relating to mycotoxins in seafoods do not exist. Schuller et al. (1983) reviewed regulations in 102 countries on mycotoxins and some of their data are shown in Table 5. Sampling procedures should also be included in regulations as mycotoxin contamination can be highly localised in a food lot. The best method of sampling is to take a large number of random sub-samples which should be well mixed before the analytical sample is taken (Rodricks and Levett, 1976).

Ideally there should be no mycotoxins present in seafoods but realistically a minimum level of 20 ng/g is tolerable.

Table 5 Maximum aflatoxin levels in foods and feeds in various in various countries

Country	Commodity	Tolerance expressed as the sum of B_1, B_2, G_1 and G_2 (ng/g)
Hongkong	all foods	15
Malaysia	all foods	zero
Philippines	coconut and peanut products (export)	20
Singapore	all foods	10 - 15
Thailand	edible oils	20
USA	all foods and feeds	20

(adopted from Schuller et al., 1983)

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SMOKING FISH: EXPERIENCE IN THE PHILIPPINES AND IN TURKEY

by

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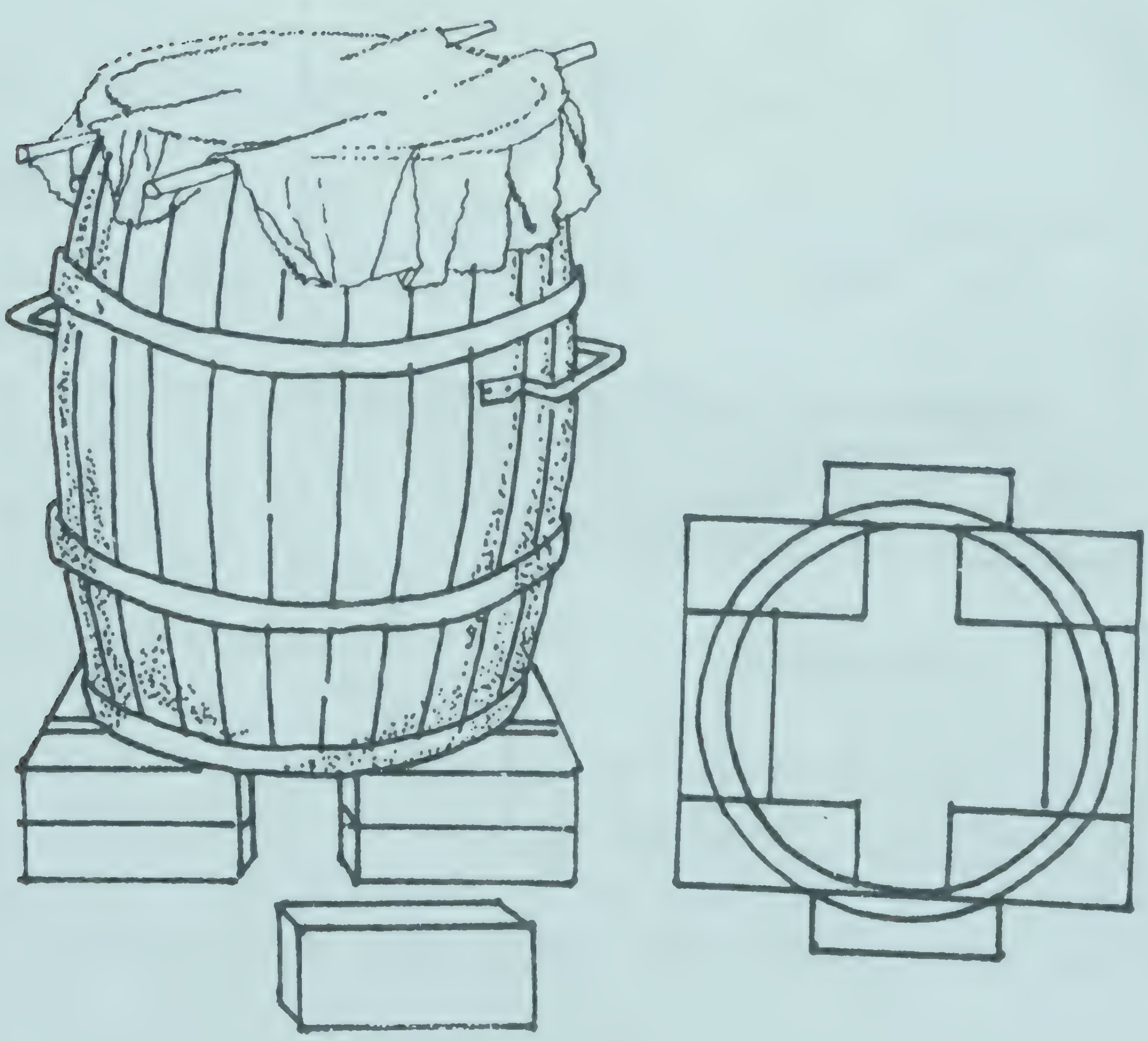
Introduction

In the Philippines, milkfish (Chanos Chanos) weighing about 300 g were smoked using the most common method of smoking in Europe at the request of several European chefs. Hot and cold smoking are the most usual methods in Europe, hot smoking being most frequently used for fish.

The following types of ovens were used:

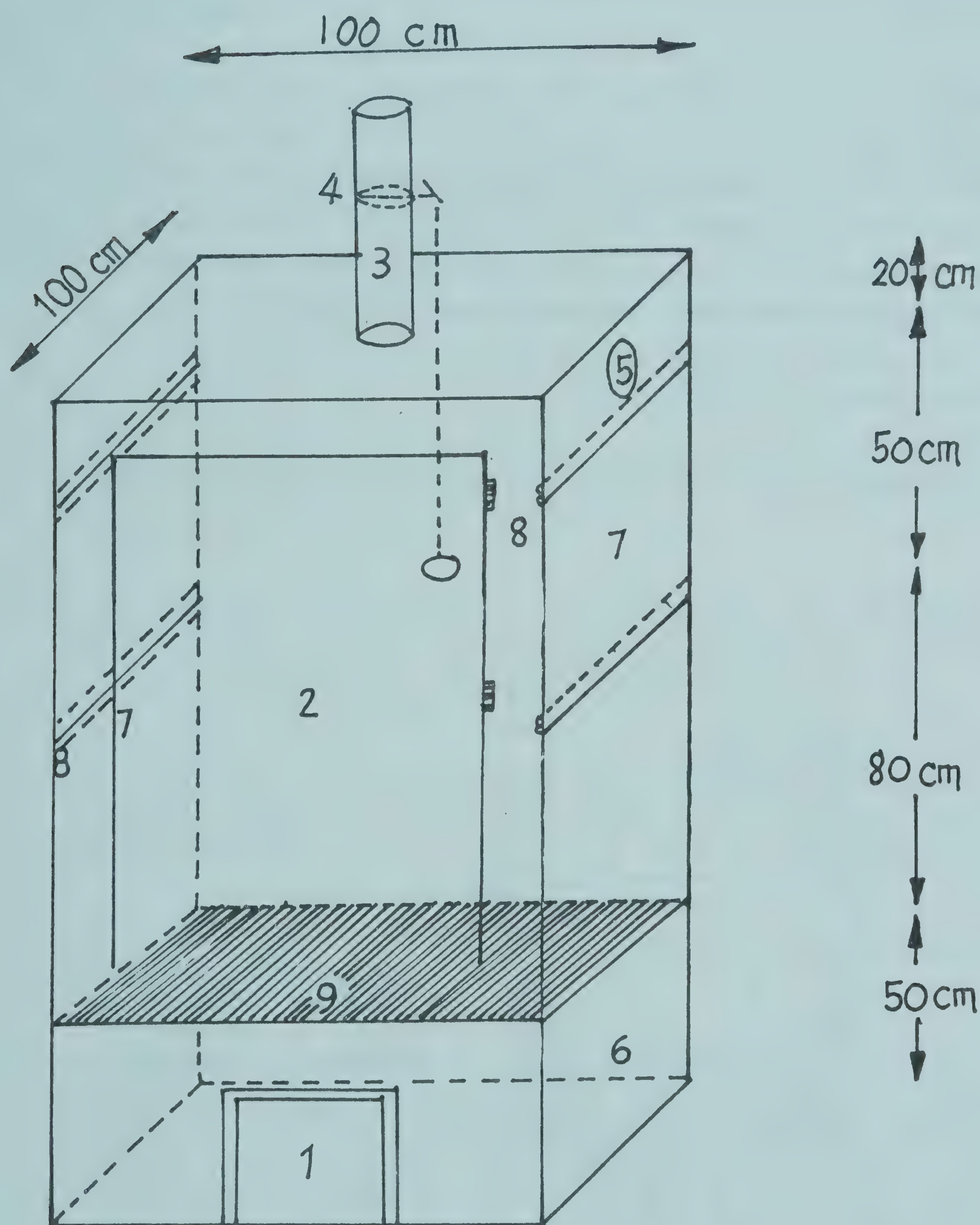
Figure 1 Traditional smoking ovens (wooden/oil barrels)



The smoking barrel is without a floor and lid. The base was made of 14 building bricks. Two bricks were used to regulate the air and the barrel was covered with a damp sack.

Mechanical smoking chambers

Smoking chambers are made of bricks or firebricks, as shown in Figure 2 below.



1. Fire door
2. Smoking chamber door
3. Ventilator pipe
4. Ventilator flap
5. Themometer
6. Fire and smoke production
7. Smoking chamber
8. Angle iron to hang the fish
9. Iron grid

Hot smoking in the Philippines and in Turkey

The various stages of hot smoking, carried out both in the Philippines and in Turkey were:

1. Cleaning the fish

   The guts, gills and kidneys are removed and washed in potable running water.

2. Salting the fish (wet salting)

   Brining is preferable to dry salting as it has the advantage of uniform salt distribution in the fish. After thorough washing, fish are brined in an 8 to 10% solution for about 12 h.

3. Preparing the fish for smoking

   After salting, the fish are quickly washed again in order to remove any remaining blood or slime. Then a cotton thread (Figure 3a) or a rustproof iron hook (Figure 3b) is attached to the fish's tail so that the fish can be hung from prepared wooden or iron rods corresponding to the diameter of the barrels or to the inside width of the smoking chambers. At this stage the water from the fish is allowed to drip off.

4. Pre-heating the smoking barrel or chamber

   While the fish are drying, the smoking barrel or chamber is pre-heated to about 100°C. Waste wood or coconut shells are used for pre-heating. When using waste wood it is important to make sure that the wood has not been chemically treated. The heat required for industrial-scale smoking facilities is usually generated by gas or electricity.

5. Hanging and smoking the fish

   After pre-heating the smoking barrel or chamber, the open fire is quenched and the fish are hung in position. It is best to cover the smoking barrel with a damp sack so that the smoke does not escape quickly. The smoke in the chamber is controlled by the ventilation flap.

   The glowing fire is now covered with sawdust or coconut husks. The oven temperature drops when the fish are hung inside and the fish are smoked at 60 to 70°C. The temperature can be controlled by opening or closing the stokehole.

Depending on the number and size of the fish, smoking takes between 1.5 and 2.5 h. Smoke-generating materials (sawdust, coconut husk) should be added to the glowing fire several times so that smoke develops properly. The dorsal fin can be pulled out to check whether the fish is sufficiently smoked.

6. Handling smoked fish

It is essential that the fish be left to cool well after smoking. For this, the fish should be hung in a cool, clean place that is free of vermin. Afterwards the smoked fish can be packed (in a material that breathes) ready for transportation and sale. The fish should be packed in two layers at most so that they are not crushed. At refrigeration temperature of 3 to 8^{0}C smoked fish can be stored for up to 7 days.

7. Smoked-filleted fish

The filleting of fish for smoking is illustrated in Figure 4.

Hotels frequently ask for filleted smoked fish. This is best vacuum-packed so that the fish does not dry out too much. When vacuum-packed, the fish can be stored for up to 4 weeks at temperatures of 13 to 18^{0}C, assuming the fish are handled and stored correctly. Whole smoked fish can also be vacuum-packed. When vacumm-packed it is important that the smoked fish or fillets are packed quickly and hygienically.

Figure 3a Hanging the fish by the tail with cotton thread

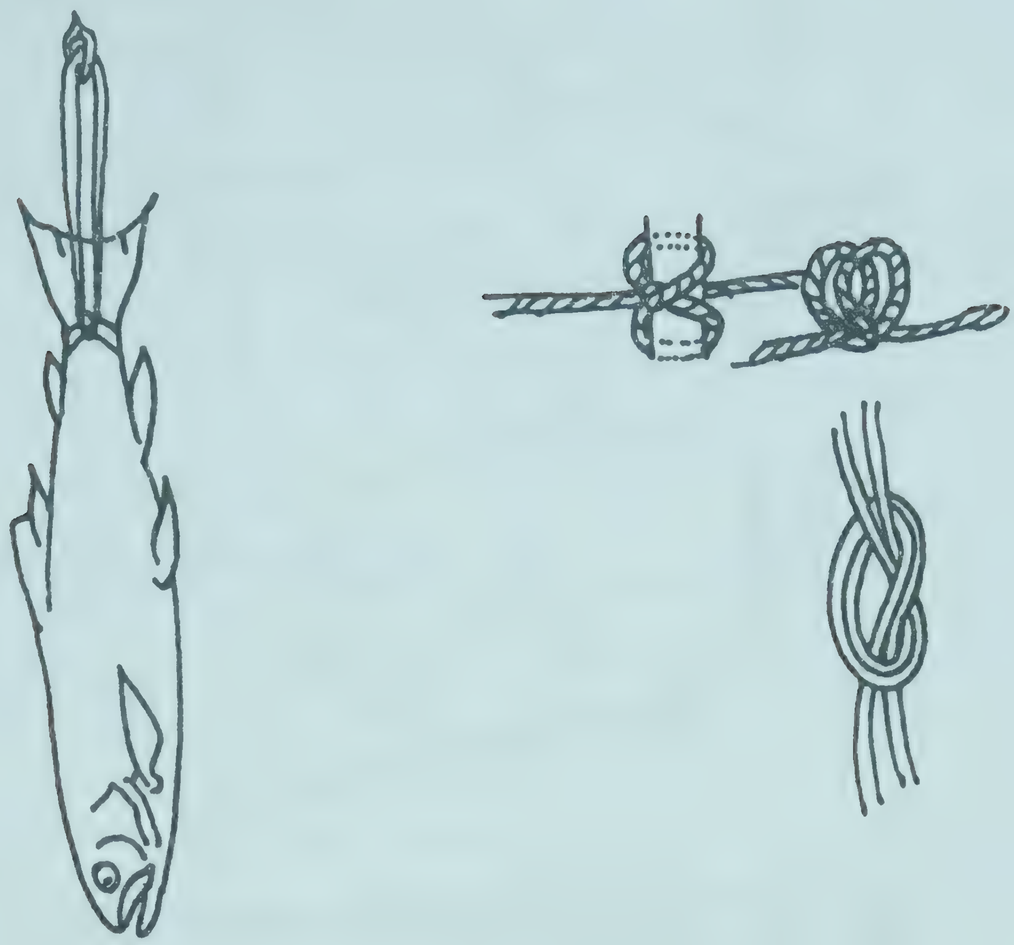
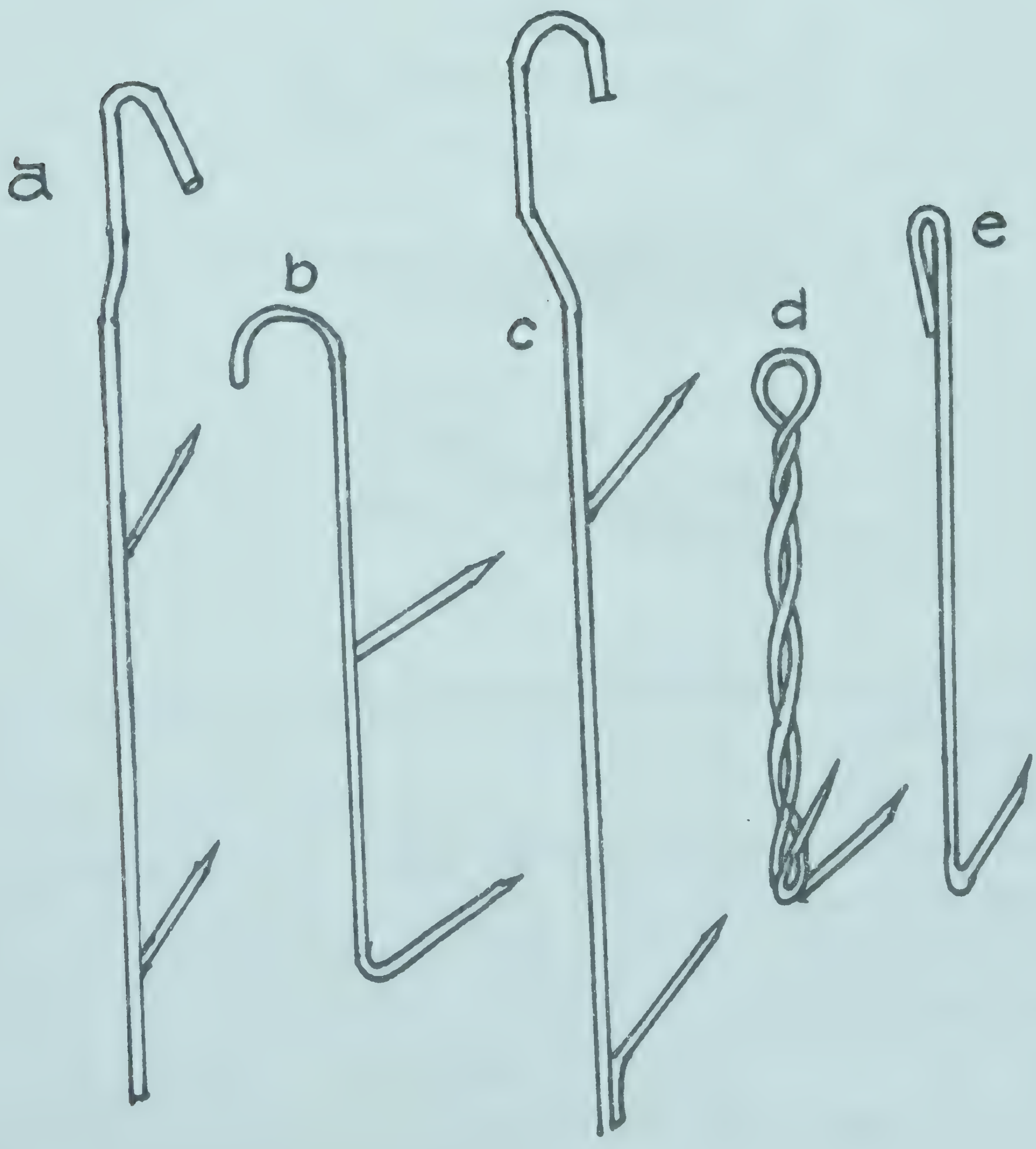


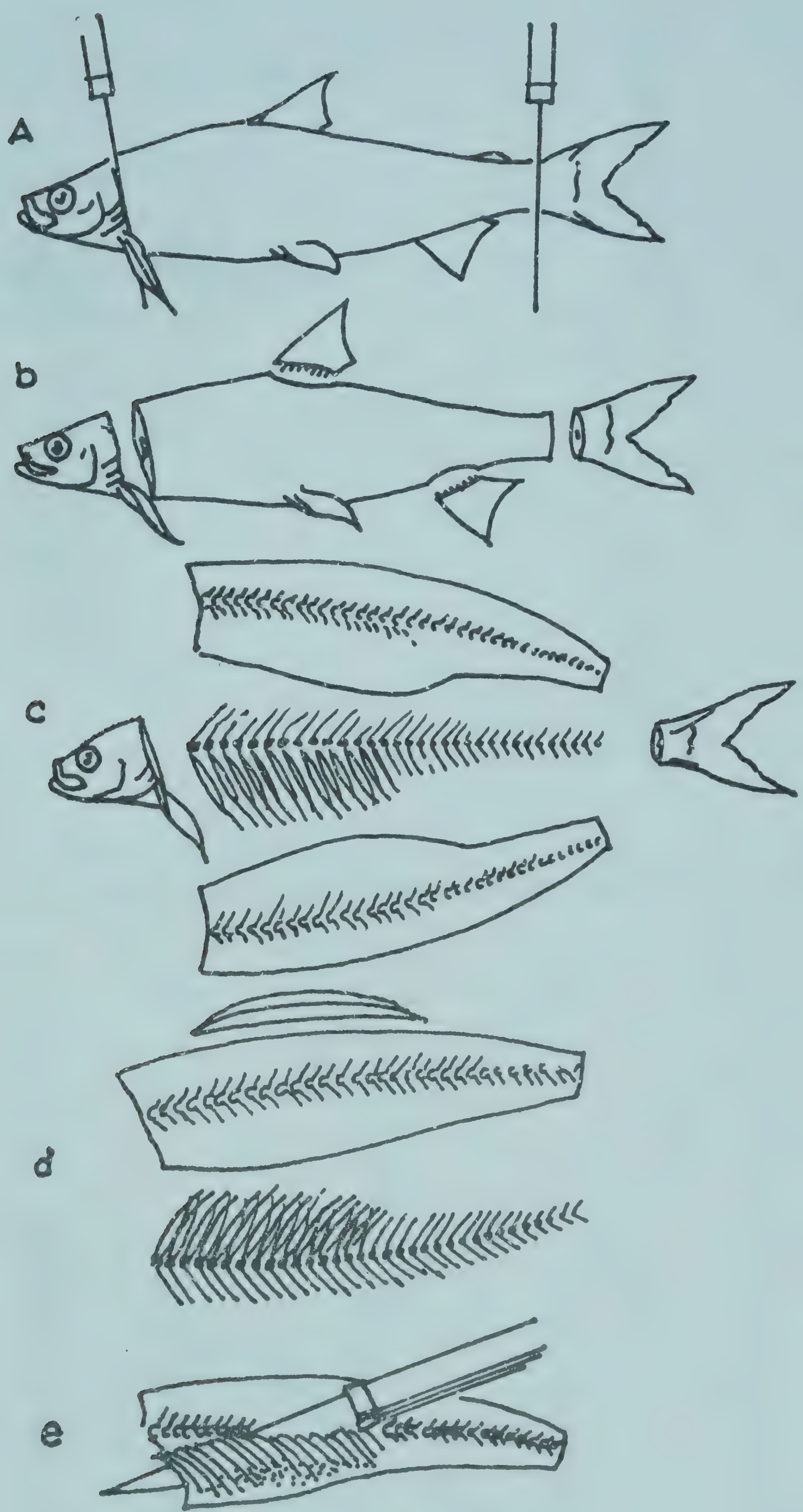
Figure 3b Hanging the fish with a rustproof iron hook



Key

a, b, c, double hook for hanging in the backbone
d, e, single hook for hanging in the throat region

Figure 4   Filleting fish



1. Head and tail are removed with diagonal cuts. The head is cut off with the pectoral fins.

2. Dorsal and anal fins are removed by hand. Slit open on the abdominal side of the tailpiece.

3. Separating the fillets

4. Removal of the dorsal fat

5. Removal of any remaining abdominal bones

Summary of the methods of fish processing and preservation in Turkey

Turkey borders on the Black Sea in the north and the Mediterranean in the south. It also has considerable potential in the form of lakes that were not been fully utilised so far.

Approximately 71% of both marine and freshwater fish are marketed fresh. Traditional methods of preservation, such as salting, drying and smoking, were of minor significance in the past, as can be seen from the following figures:

- 21% processing into fish meal and oil

- 4% salting, drying, smoking

- 1% canning

These figures relate to marine fish since freshwater fish has only been sold fresh so far.

The extreme shortage of refrigerated facilities (refrigerated storage depots and transport) means that the inland market cannot be adequately supplied with fresh fish.

TRADITIONAL METHODS OF SMOKING FISH IN THE PHILIPPINES

by

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Introduction

Fish smoking is one of the oldest method of fish preservation in the Philippines. It is believed to be introduced by the Chinese (Guevara et al., 1978). The local smoked fish is called "tinapa" and it refers to any hot smoked whole fish, 12 to 38 cm in length and golden brown to dark brown in colour. Traditional "tinapa" processing aims to preserve the fish, enhance the smoked flavour as well as improve the fish appearance. The simple processing operation does not require expensive machinery and the materials used in the production of smoked fish are locally available.

"Tinapa" is either exported or consumed locally. The total smoked fish production in 1982 was 455,640 kg valued at ₱ 6,367,802 (BFAR, 1982), of which 46% was marketed locally and 54% was exported. The exports are smoked tuna, 78% and smoked milkfish, 22% (Table 1). Smoked milkfish is either whole, splitted, boneless or soft boned and is also sold locally while tuna is mainly for export. The smoked tuna are materials for "kotsoubushi", wood-dry smoked fillets which are shaved and added to soup.

Fish smoking is not practiced throughout the country and many coastal towns prefer to dry or ferment excess fish. Six of the 12 regions smoke fish. "Tinapa" is a popular fish product in Luzon, however, some people in the Visayan islands do not eat smoked fish.

Most of the smoked fish processors are found in the Bicol region (Table 2) but production is higher in Region III which includes Metro Manila (Table 3). The Navotas Fish Port is where the majority of fish in Metro Manila are landed and the presence of freezing facilities lend availability of raw materials even during lean fishing months. Continuity of production is possible and higher plant capacity contributes to higher production of Region III.

This paper will describe two important fish smoking processes practised in the Philippines, the Navotas-Malabon method and the Salinas or Cavite

Table 1 Quantity and values of exported smoked fish within 1981-1982

Importing countries	1981		1982	
	Quantity (kg)	Value (₱)	Quantity (kg)	Value (₱)
Smoked milkfish				
Australia	15	-	-	-
Canada	-	-	8,030	82,000
France	-	-	5	-
Hongkong	3,505	36,750	12,000	138,620
Malaysia	-	-	10	-
Saudi Arabia	23,118	701,991	16,904	147,304
Thailand	10	-	-	-
USA	67,275	1,555,925	16,923	158,781
Smoked tuna				
Japan	340,844	9,760,610	186,214	3,019,162
Hongkong	-	-	1,500	55,200
Singapore	-	-	4,900	277,480
TOTAL	434,767	12,056,276	246,486	3,878,547

BFAR, 1982.

method. The raw materials, equipment, steps in processing will be discussed and the importance of the major steps in relation to the overall quality of thefinished product will be explained.

Table 2 Distribution of fish processors by region

Regions	No. of Processors*
Central Luzon (III)	109
Tagalog Provinces (IV)	139
Bicol Region (V)	466
Central Visayas (VII)	121
Negros Oriental	73
Southern Mindanao (X and XII)	94
T O T A L	1,002

* Ownership: 95%, single or household owned; 4.53%, partnership, cooperative or corporation

Payofelin and Macalincag, 1982

Table 3 Summary of smoked fish production (kg) by kind and by region, 1978

Product factory size	Regions						TOTAL
	III	IV	V	VII	XI	XII	
Smoked fish							
small scale[1]	3,840	80,507	23,125	73,886	-	39,503	220,861
medium scale[2]	208,650	85,778	230,150	20,110	93,650	-	638,338
large scale[3]	2,364,090	55,120	222,450	-	-	-	2,641,660
T O T A L	2,576,580	221,405	475,725	93,996	93,650	39,503	3,550,859

[1] 61.18% [2] 22.85% [3] 14.67%

Payofelin and Macalincag (1982)

Principles of fish smoking

Fish smoking is a method of preservation effected by a combination of salting, cooking, drying and deposition of naturally produced chemicals resulting from the thermal breakdown of wood (Cutting, 1965). Smoking can either be cold or hot depending upon the temperature of the smoke house. The temperature during cold smoking should not exceed 45°C and in hot smoking 93°C, the internal temperature reaching 30 and 60°C respectively. Smoked fish in the Philippines are cooked in brine and hot smoked.

Interrelated steps in smoking

The preservation of smoked fish is not brought about by smoke alone because initially it is concentrated only on the surface of the fish. The spoilage of the fish is brought about by enzymes and microorganisms and both must be detroyed and/or inhibited in order to preserve the fish. Preservation is brought about by the following interrelated steps.

1. Cleaning: Eviscerating and washing remove microorganisms and enzymes that are in the digestive tract. Blood, gills and false kidney are susceptible to spoilage and must be removed.

2. Salting: The amount of salt present in some smoked fish is low (5.1%) for preservation to depend solely on it. Salting process plays other roles which are vital to the overall quality of the product. Salt extracts water making the flesh firm and easy to handle. It also confers a piquant flavour and improves the appearance by leaching out blood and yielding a glossy surface.

   Application of salt can either be by dry or brine salting. Brine salting is preferred in smoked fish processing. A 70 to 80% saturated brine yields a glossy and attractive product while a 100% saturation brine results in a dull surface with powdery salt crystals. Low brine concentration (50% saturation) on the other hand makes the tissue swell slightly and gain 2 to 3% weight (FAO, 1970). The length of salting is influenced by freshness, size of fish, method of preparation, brine strength and brine temperature. Stirring the solution during brining ensures uniform salt concentration.

3. Heat treatment: In traditional smoking, fish is cooked in boiling saturated brine and during the smoking process. Heat treatment kills microorganisms and inactivates enzymes, and makes the flesh firm and less susceptible to autolysis.

4. Deposition of smoke: Smoke is produced as a result of combustion and destructive distillation of wood resulting in a complex mixture

of aliphatic and aromatic compounds in addition to water and carbon dioxide and traces of hydrogen and carbon monoxide (Cutting, 1965). The smoke components are partly responsible for the preservation and flavouring of smoked fish. It has both bactericidal and bacteriostatic action. It is also an effective anti-oxidant, providing useful protection against auto-oxidation of fatty fish. Smoke constituents are concentrated at the surface pellicle but smoke has been observed to continue diffusing from the surface to the flesh during storage (Burgess, 1958 as cited by Cutting, 1965). The smoky flavour and the toughening produced by drying result in a characteristically palatable product.

5. Drying: Drying is an essential part of the smoking process, wherein evaporation of water occurs simultaneously with smoke deposition. The amount of moisture evaporated from the fish depends upon the temperature of the smoke house and the length of smoking. The longer the fish is smoked, the more dry it becomes. The degree of drying, salting and smoking, combined with pre-treatment, trimming, cleaning, etc. which characterise various classes of smoked fish all influence in various measures the keeping quality of the products.

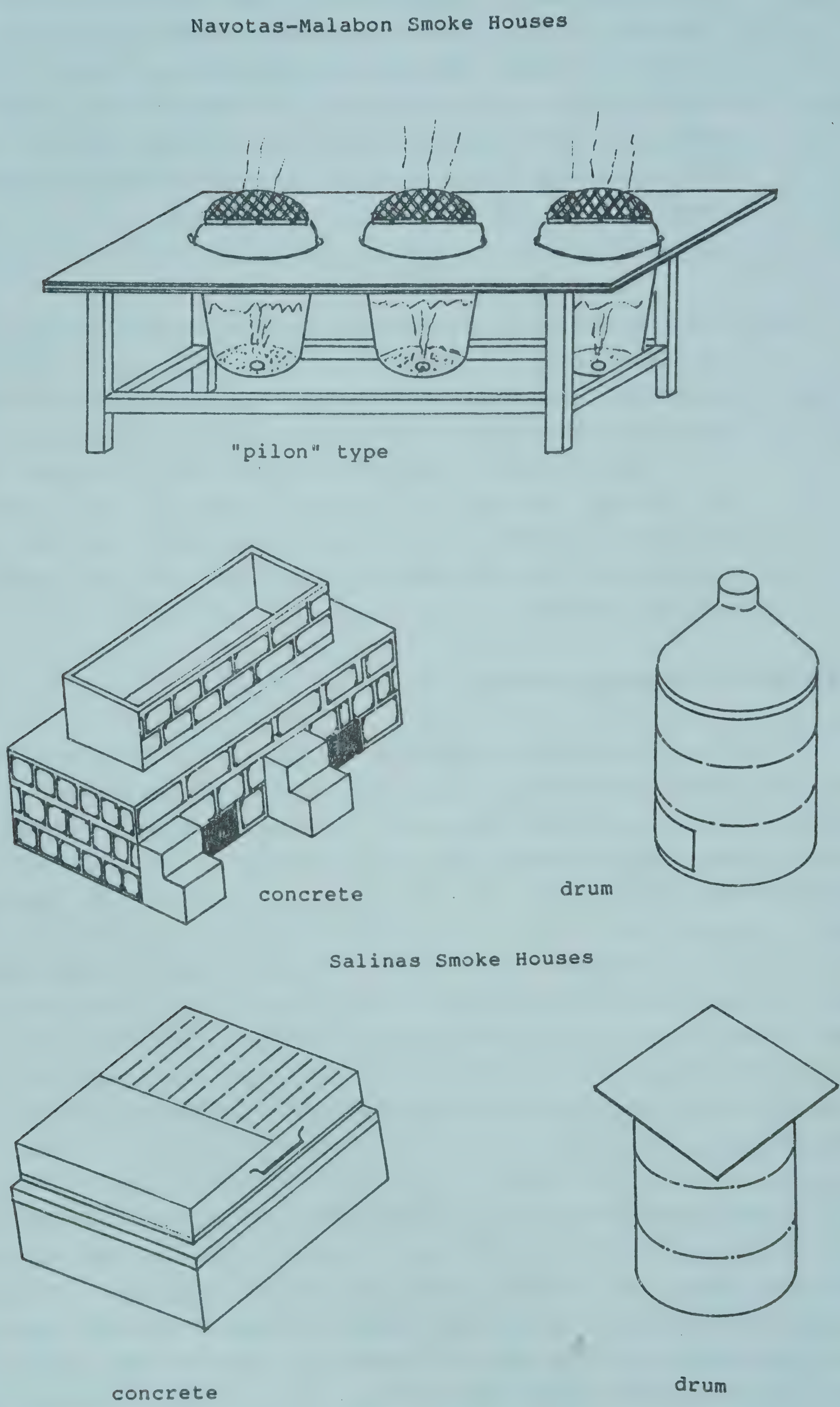
Traditional fish smoking methods

There are two general procedures for "tinapa" processing in the Philippines, the Navotas-Malabon method and the Salinas or Cavite method. Most of the processing operations practiced in the Philippines follow that of Navotas-Malabon with slight variation in smoking and brining time. All the methods do have common steps which are brining, pre-cooking and smoking.

Types of smoke houses: Figure 1 shows the most common smoke houses used. These may be made of clay as in the "pilon" type, concrete bricks or oil drums. Smoke houses used in Navotas and Malabon are provided with an opening at the bottom to allow the entrance of air while those used in Cavite are completely closed except for the opening at the top where the smoking trays are positioned.

Fuels used for smoking: Smoke house without air inlet at the bottom requires coarse and thin wood shavings. The air in between the shavings allows slow combustion. On the other hand, fine sawdust requires sufficient air in order to burn. A small hole at the bottom or side of the kiln ensures a slow combustion of sawdust. Hard wood is preferred than soft wood because the resin in the latter imparts objectionable tastes. It is difficult however to acquire pure hard wood like narra. Sawdust gathered from saw mills is a mixture of various types of wood. In most cases, it is composed of tanguile (*Shorea polysporma*), red lauan (*Shorea nigrosensis*), white lauan and palochina. In

Figure 1 Smoke houses commonly used in the Philippines



remote villages where sawdust is not readily available, coconut husk, bagasse, peanut husk or corn cobs are used.

Raw materials for smoking: Normally species of fish that have shiny scales and flesh that becomes firm after pre-cooking are smoked. The species with shiny scales are sardines, milkfish, lizard fish, shads and mullets. Many pelagic species like roundscad, big eyed scad, mackerel and tuna are also smoked. In addition to fish, other aquatic invertebrates like shrimps, mussels, oysters, squids and sea cucumber make very good smoked products.

Processing of smoked fish: (Salinas method). Figures 2 and 3 show the procedure for processing Salinas "tinapa" and equipment respectively. Sardines, milkfish, chub mackerel and roundscad are the most common species used. The smoke house is the "closed type" (without any opening at the bottom) and it is necessary to use thin and coarse fuel like wood shavings to ensure combustion. Allowing excessive air into the chamber causes the rapid burning of the wood shavings making it burst into flame. There is no brine salting process in this method. However, when the fish are not of prime quality they are immediately soaked in saturated brine to slow down spoilage, otherwise, very fresh raw materials are dried under the sun straight away and the desired salty taste is imparted during pre-cooking in saturated brine. Drying before cooking is carried out to remove surface moisture and make the skin tough. Toughening of the skin prevents the removal of the scales and and skin does not break easily maintaining the good appearance and shape.

Pre-cooking in concentrated brine solution is carried out in an open-mouthed-round bottom cast iron cauldron fixed in cooking ovens. The shape of the cooking vessel allows easy removal of cooked fish. The fuels used are rice hull and firewood. The concentrated brine is boiled and partially dried fish are cooked in it. Coarse salt is sprinkled on top of the fish to maintain the brine concentration and bamboo mattings are placed on top to weigh down the fish. Cooking time depends upon the size of the fish.

The cooked fish are cooled and arranged in trays. They are sprinkled with tap water to remove excess salt and scum on the surface. Meantime, charcoal is burned inside the smoke house, then wood shavings enough to smoke one batch of fish is placed over the live charcoal. A tray is positioned on the opening and covered. Exposure to smoke is carried out until the fish is golden brown in colour.

The smoked fish is cooled and arranged in baskets lined with banana leaves or packed in plastic bags for peddling in the city.

Navotas-Malabon method: Figures 4 and 5 show the procedure followed and the equipment used respectively. The raw materials are similar to the species processed in Cavite. The Navotas-Malabon method differs from the

Figure 2   Flow diagram showing the Salinas process of "tinapa" processing

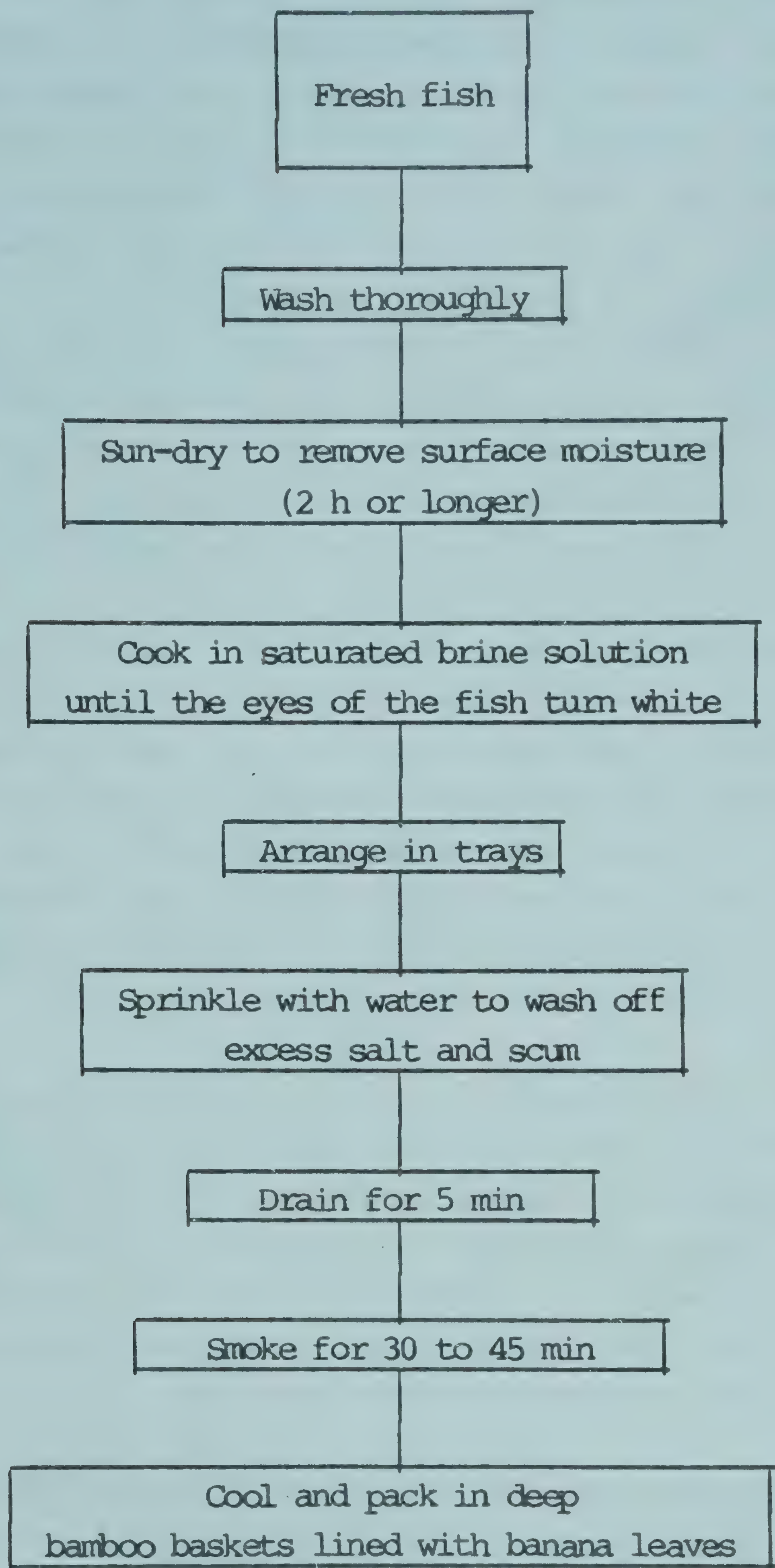
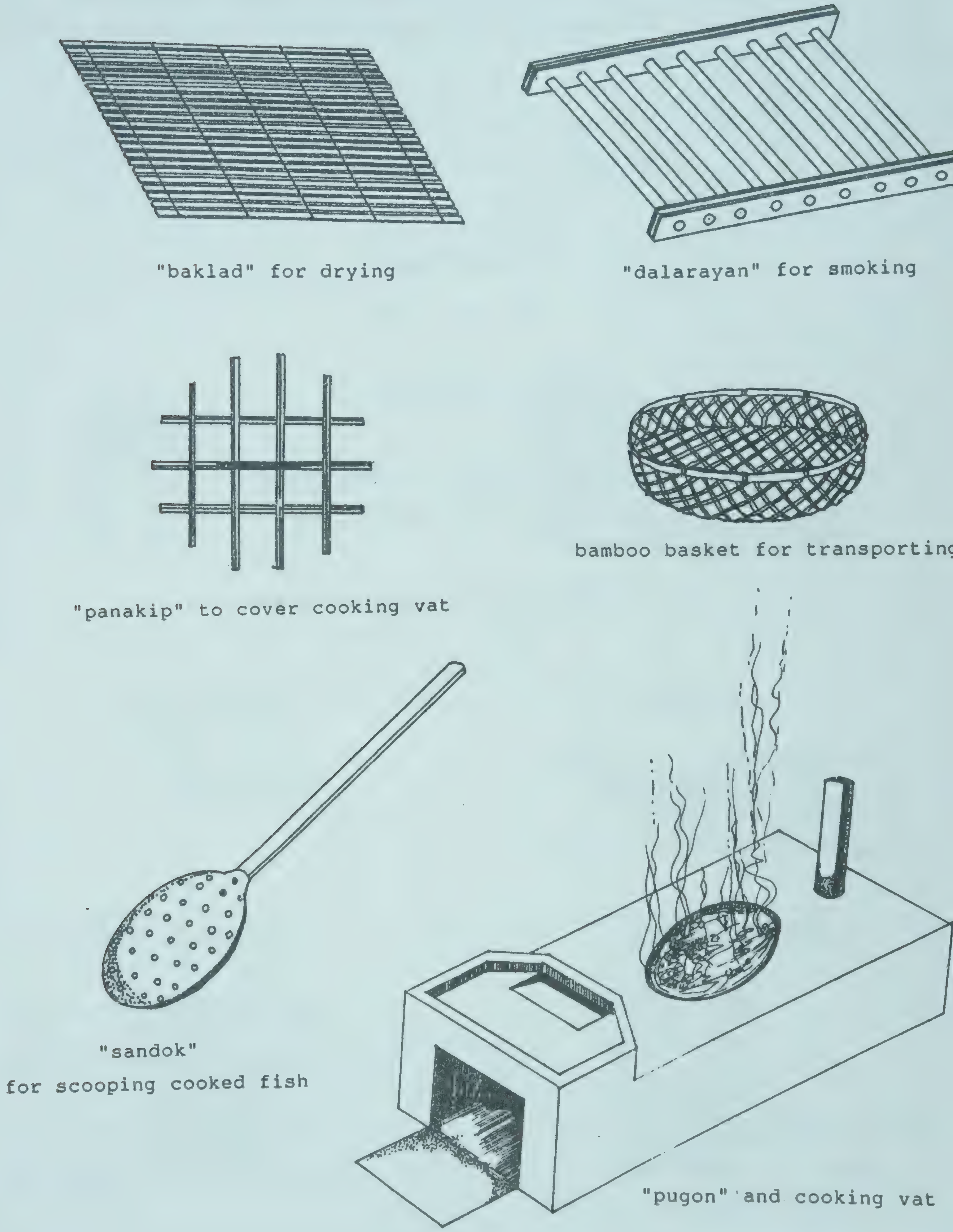


Figure 3 Equipment used for the processing and transport of Salinas "tinapa"



Salinas method in smoke house construction, fuel used, brining steps and freezing of cooked fish. The smoked fish from Navotas and Malabon are sold to different parts of Luzon. They have lower moisture content, higher salt content and stronger smokey odour. When adequately smoked the fish are golden brown, however, products sold in nearby markets are exposed to smoke for a very short time. To give the golden brown colour, the fish is brushed with oil coloured with anato seeds.

Figure 4 Flow diagram showing the Navotas-Malabon process of "tinapa" processing

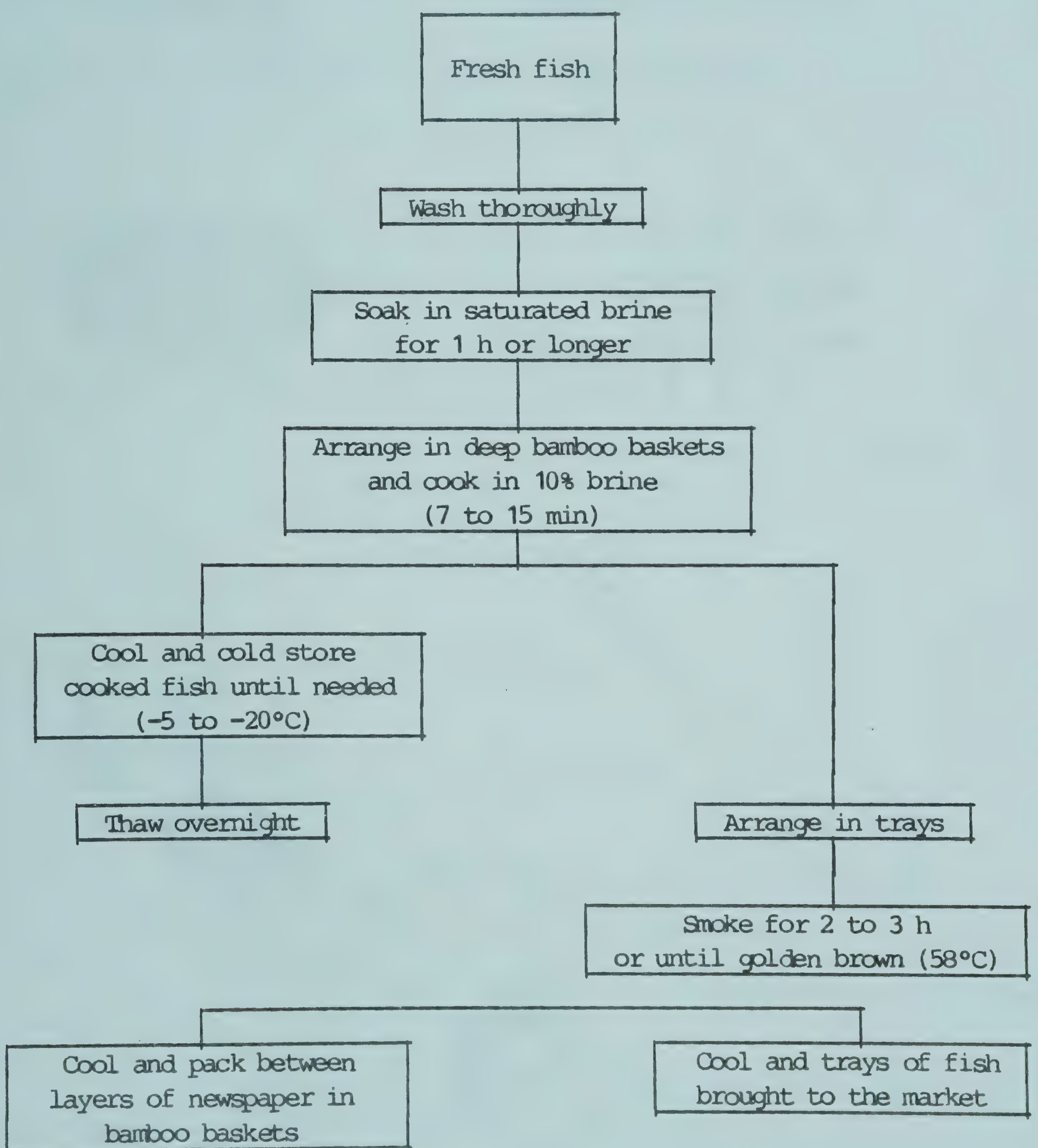
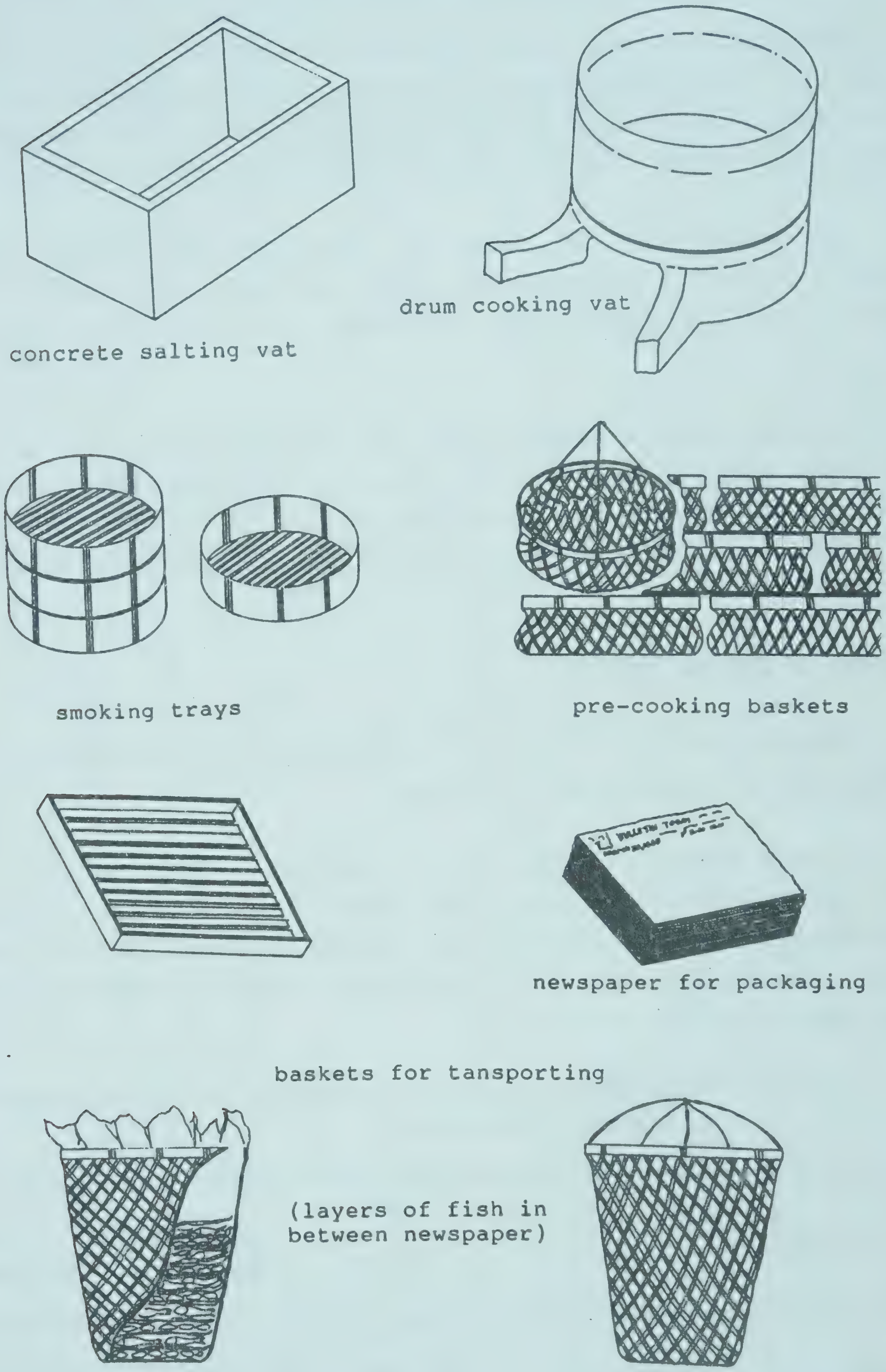


Figure 5 Equipment used for the processing and transport of Navotas-Malabon "tinapa"



The brined fish are arranged in bamboo baskets (5 to 7 kg capacity) and dipped in a boiling weak brine solution for 7 to 15 min and cooking times depend upon the size of the baskets. When raw materials are abundant and cheap, the processors salt and cook fish continously.

The cooked fish are cooled and stored in the cold storage until needed. Cold storage of pre-cooked fish is practised by big processors only. During the lean months small processors buy cooked fish from the big operators. This practice makes "tinapa" available in the market even during inclement weather.

The cooked fish are taken out from the cold storage and thawed overnight. At this stage the fish are dry and easier to handle. They are arranged in circular bamboo trays and smoked for 2 to 3 h or until golden brown.

"Tinapa" sold in nearby places are transported in the same circular bamboo trays used for smoking. The baskets are stocked together and covered with newspaper. On the other hand, fish for distant markets are smoked in small bamboo trays (4 to 5 pieces per tray) and then packed in between layers of newspaper.

Evaluation of the two methods

Acceptability and shelf-life of products and the destruction of micro-organisms during processing were evaluated.

Salinas "tinapa" is known to be preferred in Metro Manila. However, Anenias et at. (1978) concluded that smoked fish processed following the Navotas-Malabon, Salinas and Mercedes methods produced equally acceptable "tinapa". The acceptability of the product was however affected by the species of fish used (Table 4).

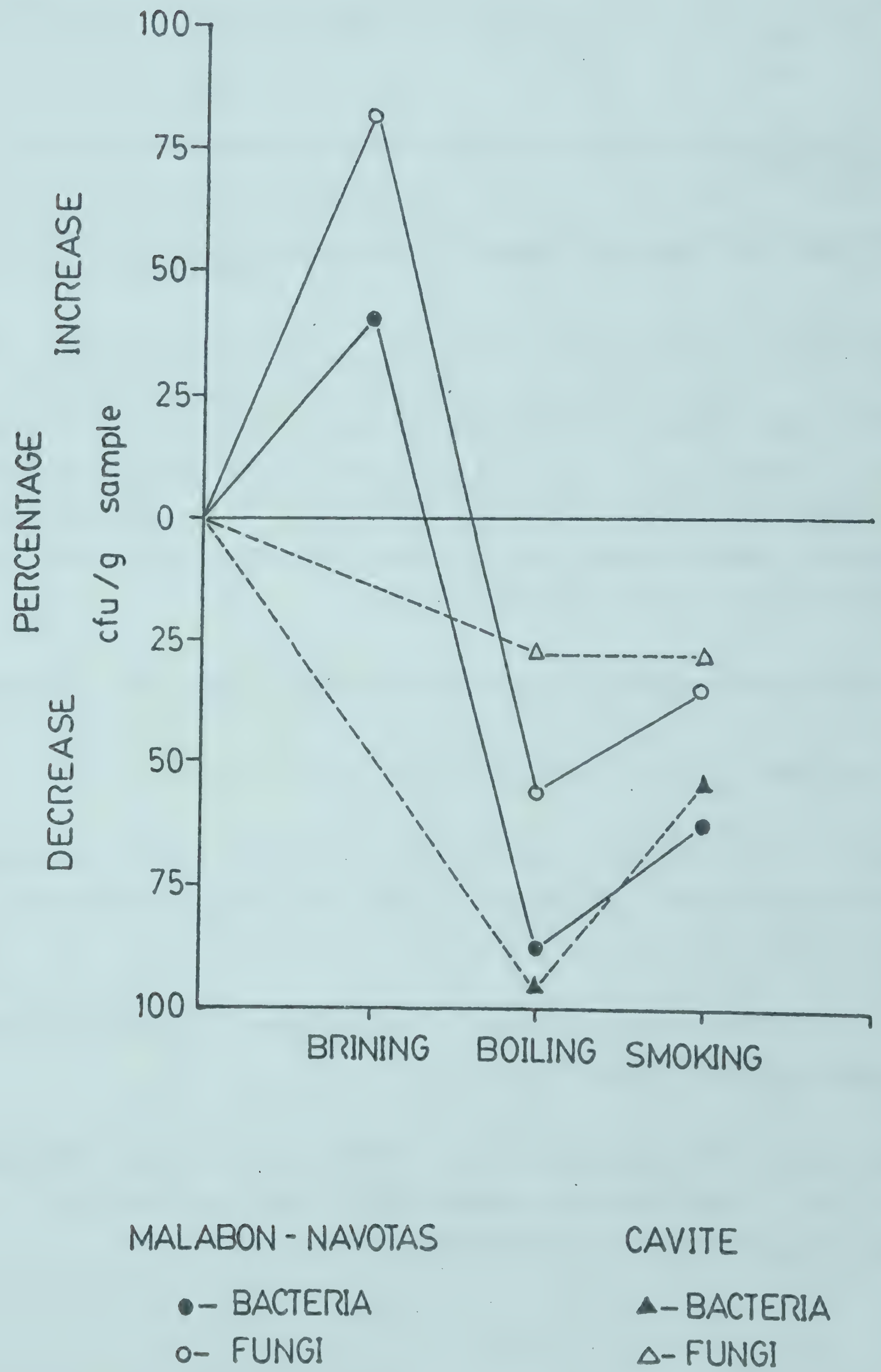
Table 4 Acceptability of different species of fish processed by 3 methods of smoking

Species	Main source*		
	Cavite	Navotas	Mercedes
Roundscad	6.9	6.7	6.7
Fimbriated herring	6.7	6.6	5.4
Freshwater milkfish	6.4	6.3	6.1
Indian sardines	5.8	6.2	6.0
Brackishwater milkfish	5.4	5.9	6.7

* scores obtained by rating samples using the Hedonic Scale (1 to 9 rating scale)
from Anenias et al. (1978)

The efficiency of the different steps in reducing the microbial load during processing showed that during brining the number of microorganisms increased (Figure 6) due to the use of old and dirty brines. The length of pre-cooking and smoking temperatures ($58^{o}C$) do not fully reduce the microbial load. During smoking, the increase in microbial load could be due to contamination from the sawdust.

Figure 6 Microbial changes in smoked sardines during processing (Mendoza, 1980)



"Tinapa" processed in Salinas showed a shorter shelf-life (Table 5) than Navotas-Malabon produce, which was attributed to higher moisture content, lower salt content and shorter exposure to smoke.

Table 5 Conditions of smoking, microbial analysis and storage life of smoked sardines

Methods	Temp. of flesh during smoking (^{o}C)	Smoking time (h)	NaCl content (%)	Moisture content (%)	TPC ($x 10^3$)	Shelf-life (days)
Navotas	60.1	2 to 4	7.6	61	9.0	4
Cavite	57.9	0.75	5.1	69.6	1.9	2

from Mendoza (1980)

Problems of the fish smoking industry in the Philippines

The problems can be summarised as follows:

1. Hygiene: Low standards of hygiene is one of the principal reasons for losses of smoked fish. Tray of fish are placed on the ground where they are exposed to contamination by the filthy flies and domestic animals. Traditional smoke houses are situated in areas with poor drainage and frequently flood during the rainy season.

2. Non-standardised methods - cooking and smoking times are variable.

3. Rapid spoilage - due to poor packaging and storage.

4. Seasonal raw materials - small processors stop their operation when raw materials are scarce. In bigger cities cold storage operators sell cooked fish at a higher price.

5. General acceptability of "tinapa" - many places in the Philippines are not accustomed to the "tinapa" flavour.

The smoked fish processing is limited only to the utilisation of few species of fish. Many marine species make a good smoked fish. Using these species new products should be developed.

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STUDY OF THE MYCOFLORA OF SMOKED ROUNDSCAD (*Decapterus macrosoma* Bleeker) FROM MALABON-TONDO AREA

by

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1. Introduction

An estimated 30% of the total fish catch in the Philippines is processed by the traditional methods of salt-drying, fermentation and smoking (Gonzales, 1976). Smoked fish or "tinapa" is produced primarily in Luzon where it is a popular traditional food (Mendoza, 1980). Species which are usually smoked due to their abundance and year-round availability include milkfish, mackerel, sardines and roundscad. The method used by the industry is hot-smoking with temperatures ranging from 70 up to 100°C (Anenias *et al*., 1978), temperatures hot enough to broil the fish. The process includes pre-cooking which is considered to be adopted from the Chinese (Cutting, 1965). Pre-cooking seems to be the main factor in prolonging the shelf-life of the product which usually stays without visible microbial growth from 3 to 5 days at ambient storage temperatures.

There are two methods of hot-smoking "tinapa" which is marketed in Metro Manila. These are the Salinas method used in Cavite, and the method practised in Malabon, Navotas and Tondo. The Salinas method produces smoked fish with full rounded bodies and occassionally burned skin due to very high temperature in the smoking chambers. Produce from Malabon and Tondo are identifiable in the market by the deformed bodies of the fish (slight to medium deformation due to stacking in cold storage) as well as uneven smoke colour because of skin damage during stacking. The two processes are briefly outlined in Figures 1 and 2.

There are at least two distinctions between the processes described. One is the absence of brining in the Salinas method which accounts for the product's low salt content of around 3% and high moisture content of 63 to 69%. The Malabon-Tondo method produces "tinapa" with 4.4 to 9% salt content and 40 to 65% moisture content (Mendoza, 1980; Nieto and Trinidad, 1982). The Salinas

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"tinapa" is characteristically juicy and tender with just the right amount of saltiness whereas the Malabon-Tondo product is less juicy, a little tough and is more salty. Another difference is the use of cold storage to keep pre-cooked fish in the Malabon-Tondo method. Fish are stored during the peak season when the price of the fish is lowest. The small-scale processors of Malabon and Tondo pool their materials in a common cold store. Small quantities sufficient for a day's processing are taken out of storage, smoked and marketed on the same day. The daily supply of "tinapa" in Metro Manila is provided by the small-scale processors of Cavite, Malabon and Tondo. The few large-scale processor in Malabon transport their produce to the provinces as far as Isabela and Cagayan (Mendoza, 1980).

One area of concern regarding the Malabon-Tondo process is the maintenance of temperature during cold storage. Since the storage is open to many small-scale processors, overcrowding the area with pre-cooked fish is possible. It was observed during at least 2 visits that some baskets of pre-cooked fish coming from cold storage were covered with white or greenish fungal growth or yellow slime of yeast or bacteria indicating that the storage temperature was not low enough to prevent microbial growth. However, the contaminated fish were nevertheless smoked and came out a golden brown colour from the smoking drum.

It is a common household and commercial practice to ignore the small tufts of white vegetative growth and use the product. Consumers' and producers' losses taken together are significant. Another factor to consider is the occurrence of moulds in pre-cooked fish during cold storage in Malabon-Tondo process. It is possible that the fungi covering the surface of the storage baskets produce mycotoxins that are carcinogenic. These metabolites may diffuse into the fish flesh and resist destruction by ordinary cooking as has been observed for grains (Stoloff and Trucksess, 1981). The purpose of this study was to investigate the fungal flora of smoked roundscad particularly that from Malabon-Tondo area and to determine whether the physico-chemical conditions in marketed samples are within the range that would allow production of harmful fungal metabolites like aflatoxins.

The objectives of this study were:

- To determine the mycoflora of commercial smoked roundscad from Malabon-Tondo area;

- To relate the mycoflora to the water activity, phenol content, salt content and pH of the samples;

- To screen for potential aflatoxin producing isolates from smoked roundscad.

Figure 1 Flow chart showing the "Salinas" method of smoking (Mendoza, 1980)

FISH

↓

Wash in tap water

↓

Dry under the sun for 2 h

↓

Cook in boiling saturated brine until eyes turn white

↓

Arrange in smoking trays

↓

Sprinkle with water to remove scum

↓

Drain for a few minutes

↓

Smoke for 30 to 45 min at 59°C

↓

Cool and pack in baskets covered with banana leaves

Figure 2 Flow chart showing the Malabon-Tondo process of smoking fish (after Anenias *et al.*, 1978)

FISH

↓

Wash in tap water

↓

Soak in saturated brine in tanks for 30 min or more

↓

Cook in weak brine 7 to 15 min

↓

Arrange in storage baskets
keep in cold storage for 2 weeks to 4 months

↓

Arrange in smoking trays

↓

Sprinkle-wash

↓

Drain

↓

Smoke for 20 min or longer until fish
attains the desired colour or texture

↓

Cool in smoking trays, cover with newspaper

2. Materials and methods

2.1 Sampling

Smoked roundscad (Decapterus macrosoma Bleeker) were purchased from 6 markets in Metro Manila from February to May 1983. Samples were taken from the following market outlets: Divisoria and Quinta markets (Manila); Monumento and Sangandaan markets (Caloocan City); and Cloverleaf and Murphy markets in Quezon City. Samples were purchased during late afternoons since it was around this time that the daily produce from Tondo and Malabon reach the markets. A half kilo of fish from each tray was bought and immediately placed into sterile plastic bags and sealed. Samples were refrigerated and analysed the following morning.

2.2 Isolation of fungi

Fungi were enumerated using the pour plate method in triplicate on potato dextrose agar with rose bengal (Oxoid) and dichloran-glycerol agar (DG18) and malt/yeast extract with glucose (40%) MY40g (Hocking, 1981). Plates were incubated at room temperature for 7 to 14 days.

2.3 Water activity determination

The water activity (A_w) of the samples was determined by equilibration with microcrystalline cellulose, the isotherm of which was previously determined (Lupin, 1982). This method was chosen for its simplicity, reported accuracy and shorter duration of equilibration.

2.4 Moisture content determination

The moisture content of each sample was determined in duplicates using infra-red moisture balance.

2.5 Phenol content determination

The amount of phenol in the samples was determined by Tucker's modified spectrophotometric method (Tucker, 1942). Absorbance of the sample extracts were read from a standard curve.

2.6 pH and NaCl content

These were determined by the methods of the AOAC (1980).

2.7 Identification of fungi

The isolates were maintained on Czapek Dox Agar slants and identified based on morphological characteristics.

2.8 Screening for presumptive aflatoxin production

Isolates identified as Aspergillus flavus were screened for possible aflatoxin production using the medium of Torrey and Marth (1976). The fluorescence of the agar immediate to the fungal growth was determined at 365 nm under a Chromato View UV chamber. The fluorescence of the isolates was compared with that of a reference organism A. flavus NRRL 2999. Intensity of fluorescence was recorded as (+++) for heavy intensity, (++) for medium intensity, (+) for light intensity and (-) for negative fluorescence.

3. Results and discussion

3.1 Physico-chemical characteristics of smoked roundscad

3.1.1 Water activity

The physico-chemical characteristics of the samples are given in Tables 1 and 2. Table 2 shows all 22 samples are within the range of high moisture foods, with A_w values from 0.855 to 0.980. The 2 samples from Cavite (17 and 18) had A_w 0.955 and 0.975 respectively. These were comparable to the A_w of most of the produce from Tondo which ranged from 0.980 to 0.927. The moisture content from 43 to 67% were in agreement to values reported for smoked fish (Anenias et al., 1978; Nieto and Trinidad, 1982). About 50% of the samples had 43 to 50% moisture content while about 40% had 51 to 62%.

3.1.2 Phenol content

The phenol content of the samples showed a range from 0.81 to 2.14 mg/25 g sample. From Table 2, 43% of samples had 0.81 to 1.00 mg/25 g, another 43% had 1.10 to 1.50 mg/25 g and 13% had 1.51 to 2.14 mg/25 g phenol. Lower values were observed in most of Malabon samples except samples 35 and 36 (Table 1). Low phenol content may be due to short smoking time, as in sample 33 which did not acquire the characteristic golden brown colour of smoked fish and appeared more like plain boiled fish. Another explanation is that the Malabon samples had been in the market for longer than a day, during which much of the volatile phenol may have been lost. Tondo products, are produced in smaller quantities and are immediately marketed, thus exposure to ambient storage conditions are minimal.

3.1.3 Salt content

Tondo samples had lower salt content and ranged from 1.97 to 4.32% (Table 1). Higher salt contents from 5.1 to 5.5% were observed in samples 23, 25 and 26. This could be a reflection of the variability of brining practices among Tondo processors. Malabon samples consistently had more than 5% salt

Table 1 Physico-chemical characteristics of smoked roundscad

Sample	Source	A_w	Phenol content (mg/25g)	Salt content (%)	pH	Moisture content (%)
17	Divisoria (Cavite)	0.975	-	-	6.05	67.47
18	Divisoria (Cavite)	0.955	-	-	5.67	63.67
19	Monumento (Malabon)	0.927	-	-	5.88	58.90
20	Monumento (Malabon)	0.875	-	-	5.76	52.22
21	Sangandaan (Malabon)	0.940	-	-	6.03	60.55
22	Sangandaan (Malabon)	0.950	-	-	5.93	58.53
23	Murphy (Tondo)	0.938	2.14	5.09	5.44	46.44
24	Quinta (Tondo)	0.943	1.66	4.32	5.42	49.84
25	Quinta (Tondo)	0.9393	1.10	5.48	5.41	45.79
26	Murphy (Tondo)	0.927	1.28	5.51	5.26	50.72
29	Monumento (Tondo)	0.953	1.14	3.87	5.52	55.32
30	Monumento (Tondo)	0.965	1.14	3.02	5.54	55.16
31	Sangandaan (Malabon)	0.920	0.82	5.85	5.47	48.47
32	Sangandaan (Malabon)	0.855	1.00	6.86	5.46	45.08
33	Cloverleaf (Tondo)	0.980	0.81	1.97	5.89	59.54
34	Cloverleaf (Malabon)	0.890	0.88	5.45	5.53	43.83
35	Quinta (Malabon)	-	1.35	5.38	5.56	52.11
36	Quinta (Malabon)	-	1.35	5.31	5.62	47.36
37	Quinta (Malabon)	-	1.09	5.39	5.73	50.00
38	Quinta (Malabon)	-	1.03	4.30	5.79	50.48
39	Quinta (Malabon)	-	0.81	4.30	5.88	51.36
40	Quinta (Malabon)	-	1.38	4.95	5.88	48.67

Table 2 Frequency distribution of the samples in given ranges of physico-chemical parameters

Parameter range	Percentage of samples within the range
A_w	
0.855-0.900	18
0.910-0.950	50
0.951-0.980	31
Moisture content (%)	
43-50	50
51-62	41
63-67	9
Phenol content (mg/25g)	
0.81-1.00	43
0.10-1.50	43
1.51-2.14	13
Salt content (%)	
1.97-3.50	12
3.60-5.00	36
5.10-6.86	50
pH	
5.00-5.50	27
5.51-6.05	72

content, the highest being 6.86% (Sample 32) and indicates that Malabon processors are consistent in their brining practices in order to increase the storage life for out-of-town markets.

3.1.4 pH

The pH values fell within a narrow range of 5.26 to 6.05. Two-thirds of the samples had pH readings of 5.51 to 6.05. These values are considered favorable for yeast and fungal growth.

Table 3 Range of microbial load and physico-chemical characteristics of samples

Media used	cfu/g	No. of samples	A_w	Range of Sample Parameters: moisture content	Phenol mg/25 g	Salt (%)	pH
DG_{18}							
	6	2	-	50.5	1.03-1.09	4.3 -5.4	5.73-5.79
	6-24	13	0.875-0.965	45-61	0.81-2.14	3.02-5.85	5.3 -6.05
	25-81	3	0.855-0.955	45-67	1.00	6.86	5.46-6.05
	82-100	1	0.980	59.5	-	1.97	5.89
	101-119	2	0.875-0.89	44-52	0.88	5.45	5.53-5.76
MY40G							
	6	0	-	-	-	-	-
	6-24	14	0.855-0.965	45-64	0.81-2.14	3.02-6.86	5.3-6.03
	25-81	5	0.920-0.975	46-67	0.81-2.14	5.0 -5.85	5.44-6.05
	82-100	1	0.890	43.8	0.88	5.45	5.53
	101-119	1	0.875	52.2	-	-	5.76
PDA							
	6	3	0.927	47-52	1.28-1.35	5.3-5.4	5.3-5.6
	6-24	11	0.920-0.965	46-64	0.81-2.14	3.0-5.85	5.5-6.0
	25-81	5	0.855-0.975	45-67	0.81-1.28	4.3-6.86	5.3-6.0
	82-100	2	0.890-0.980	44-60	0.81-0.88	1.97-5.45	5.5-5.9
	101-119	-	-	-	-	-	-

Note: Some samples due to limitations on availability of materials were not tested for A_w, phenol and salt. This explains the single entry in some instances where more than 1 entry is

Table 4 Frequency of occurrence of fungi in smoked roundscad

Fungi	(%) Frequency	A_W range	Phenol range	Salt range (%)	pH range
A. flavus	38	0.85-0.980	0.81-2.14	1.97-6.86	5.42-5.89
A. foetidus	25	0.855-0.965	0.82-1.28	3.10-6.86	5.26-5.93
A. glaucus grp.	8	0.927	0.81	4.30	5.88
A. niger	88	0.855-0.980	0.81-2.14	1.97-6.86	5.26-6.05
A. oryzae	4	0.980	0.81	1.97	5.89
A. tamarii	13	0.855-0.980	0.81-1.0	1.97-6.86	5.46-5.89
A. terreus	4	0.89	0.88	5.45	5.53
Aspergillus sp.	8	0.93-0.950	1.10	5.48	5.4-5.93
Aureobasidium sp.	8	0.975	1.35	5.38	5.6-6.05
Botryotrichum sp.	13	0.890-0.980	0.86-2.14	5.1-6.0	5.44-5.73
Chaetomium sp.	13	0.935-0.965	0.86-1.35	3.0-6.0	5.5-5.73
Circinella sp.	4	0.950	-*	-*	5.93
Cladosporium spp.	13	0.955	1.38	4.95	5.93
Curvularia sp.	17	0.81-1.38	4.3-6.0	5.88	
Gliocladium sp.	4	0.975	-*	-*	6.05
Monascus sp.	4	0.927	-*	-*	5.88
Mucor sp.	25	0.855-0.940	0.81-2.14	5.1-6.86	5.3-6.0
Fusarium spp.	29	0.876-0.975	0.86-1.28	3.7-6.0	5.3-6.0
Paecilomyces varioti	42	0.875-0.950	0.81-1.28	4.3-6.0	5.26-5.93
Penicillium spp.	88	0.855-0.980	0.81-2.14	1.97-6.86	5.42-6.05
Trichoderma sp.	8	0.938-0.975	2.14	5.1	5.44-6.05
Syncephalastrum sp.	13	0.927-0.975	0.81-2.14	-*	5.88-6.05
Yeasts	96	0.855-0.980	0.81-2.14	5.97-6.86	5.97-6.05

* not analysed

Table 5 Minimum A_w and temperature for growth of fungi

Species	Toxin	Min. A_w for growth	Min. A_w toxin	Min. T^oC
Aspergillus chevalieri	gliotoxin sterigmatocystin	0.71		10
A. flavus	aflatoxins	0.78	0.80	10
A. fumigatus	fumigillin	0.82		12
A. nidulans	sterigmatocstin	0.83		12
A. niger	oxalate	0.85		12
A. ochraceous	ochratoxin	0.75	0.81	10
A. parasiticus	aflatoxins	0.70	0.80	
A. versicolor	sterigmatocystin	0.83		6
Cladosporium herbarum	epicladosporic acid	0.88		-7
Fusarium rosem	zearalenon	-		-
F. trincinctum	trichothecens	-		-
Penicillium brevicompactum	mycophenolic acid	0.81		-2
P. citrinum	citrinin	0.80		12
P. patulum	patulin	0.81	0.85	-
P. roquefortii	patulin PR toxin	-		-
Stachybotrys atra	stachybotryotoxins	0.94		2
Wallemia sp.		0.75		-

Adapted from Lupin, 1982; Northolt and Bullerman, 1982

4. Conclusion

1. Commercial smoked roundscad from Malabon-Tondo area were contaminated with a variety of fungi that included species of *Aspergillus*, *Paecilomyces*, *Penicillium*, and yeasts. Fungal contamination was presumed to include surface contamination during and after smoking plus mycelial growth during cold storage of pre-cooked fish.

2. The highest mould counts were associated with samples of lower A_w. The phenol and salt content of the samples were at levels that were non-inhibitory to microbial growth. The pH of the samples fell within a range favorable for mould growth.

3. Fifty per cent of the isolates of *Aspergillus flavus* were positive for presumptive aflatoxin production.

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PRODUCTION OF SMOKED SPANISH MACKEREL

by

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1. Introduction

Spanish mackerel (Scomberomorus commerson) locally known as "tangigue" is a white-fleshed commercially important species caught off the Philippines. The common size of this fish is 90 to 220 cm fork length.

Between 1978 and 1981 the world catch of this species increased from 55,452 to 72,281 t. The Philippines, along with Indonesia, Sri Lanka, Democratic Republic of Yemen and Pakistan were reported to have the largest catch during this period (Collette and Naven, 1984). BFAR (1982) reported a total catch of 11,924 t in 1978 which increased to 17,269 t in 1982 with the municipal fisheries producing 65 to 90% of the total catch. In Navotas Fishery Port alone, the country's largest, 757,665 kg of "tangigue" were landed in 1984 and more recently 18,675 and 23,310 kg between January and February of 1985 (PFDA, 1985). This species has a high commercial value because of the local demand for very fresh fish used as "sashimi" and pickled "kilawin tangigue". This study was conducted to develop methods for the production of smoked "tangigue" for both local and export markets.

2. Methodology

2.1 Raw Material

Fresh Spanish mackerel caught off the Tayabas and Lamon Bays were obtained from a local market. Each fish weighed about 8 to 10 kg. Preparation for smoking involved filleting, deboning, skinning and thorough washing (Figure 1). The fillets were cut into halves (along the backbone) and the dark meat removed.

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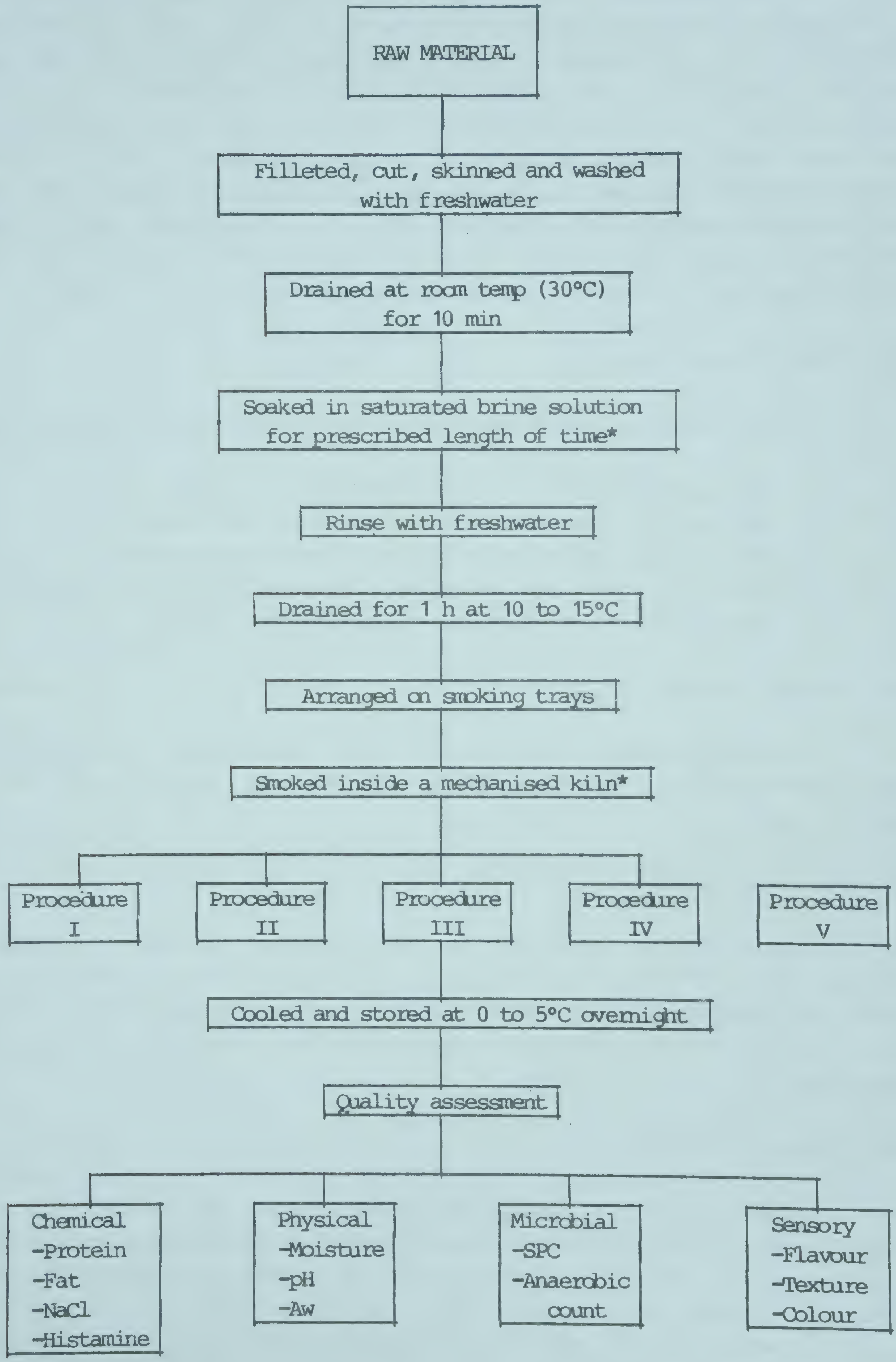
Figure 1 Schematic diagram of experimental design of the smoking procedure for Spanish mackerel (*Scomberomorus comerson*)



* see text

2.2 Smoking procedures

Fillets were soaked in saturated brine for 30 min. The average size of fillets were 25 x 9 x 4 cm and weighed approximately 270 g. After 1 h equilibration inside a chillroom (7 to 10^{o}C), fillets were smoked using an Afos Torry Kiln Model 20, following five time-temperature combinations. The first procedure involved smoking at 40^{o}C for 4 h and 83^{o}C for 1 h. Procedure II was a cold smoking process (30 to 35^{o}C) for 8 h; Procedure III was initially cold smoking at 35^{o}C for 3 h then at 65^{o}C for 3 h; Procedure IV was at 45^{o}C for 8 h and Procedure V at 55^{o}C for 8 h. The smoked samples were wrapped in an aluminum foil and stored overnight at 5^{o}C. Analyses of the initial quality of the smoked products were carried out the following day.

2.3 Chemical tests

The following tests were conducted on the freshly smoked samples.

- Salt analysis by modified Volhard Method
- Fat analysis following Bligh and Dyer extraction method
- Total protein determination by the Kjeldahl-Gunning method
- Histamine content was determined throughout the smoking processes using the fluorometric method of Taylor *et al*. (1978).

2.4 Physical methods

Moisture content was determined by direct reading using an Ohaus infrared moisture balance and water activity (A_W) measured using a Lufft water activity meter.

2.5 Microbial methods

Standard plate count (SPC) at 20^{o}C expressed as number of colony forming units per gram of sample (cfu/g), was carried out using Plate Count Agar. For anaerobic tests, two media (Perfringens Agar and Cooked Meat Medium) were used to check the presence of anaerobic spores, especially *Clostridium botulinum*.

2.6 Sensory evaluation

A panel of 15 to 30 members were asked to assess the acceptability of smoked samples. Choice of panellists was limited to possible consumers/buyers of such product. The samples were presented in a ready-to-eat manner, sliced thinly and chilled (approximately 20^{o}C). Quality attributes such as flavour (salt and smoke), texture and appearance, particularly colour, were analysed (Table 1). A 6-point scale from poor (1) to excellent (6) was used by the taste panel. Analysis of variance and Turkey's test were used to determine significant differences among samples (Gatchalian, 1981; Larmond, 1977).

Table 1 Scoresheet for smoked Spanish mackerel

NAME: ____________________ PANELLIST NO. ________

NAME OF PRODUCT: Smoked tangigue DATE: ____________

Instructions:

You are presented with samples of smoked tangigue. Evaluate them for odour, appearance and flavour, then rate them based on the following scale:

_____ Excellent	_____ Fair
_____ Very good	_____ Poor
_____ Good	_____ Very Poor

ODOUR:

Code	Rating	Reason/Comment
____	_____	______________________________
____	_____	______________________________

APPEARANCE:

Code	Rating	Reason/Comment
____	_____	______________________________
____	_____	______________________________

FLAVOUR:

Code	Rating	Reason/Comment
____	_____	______________________________
____	_____	______________________________

COMMENTS:

Please include comment on texture and drip.

____

____

____

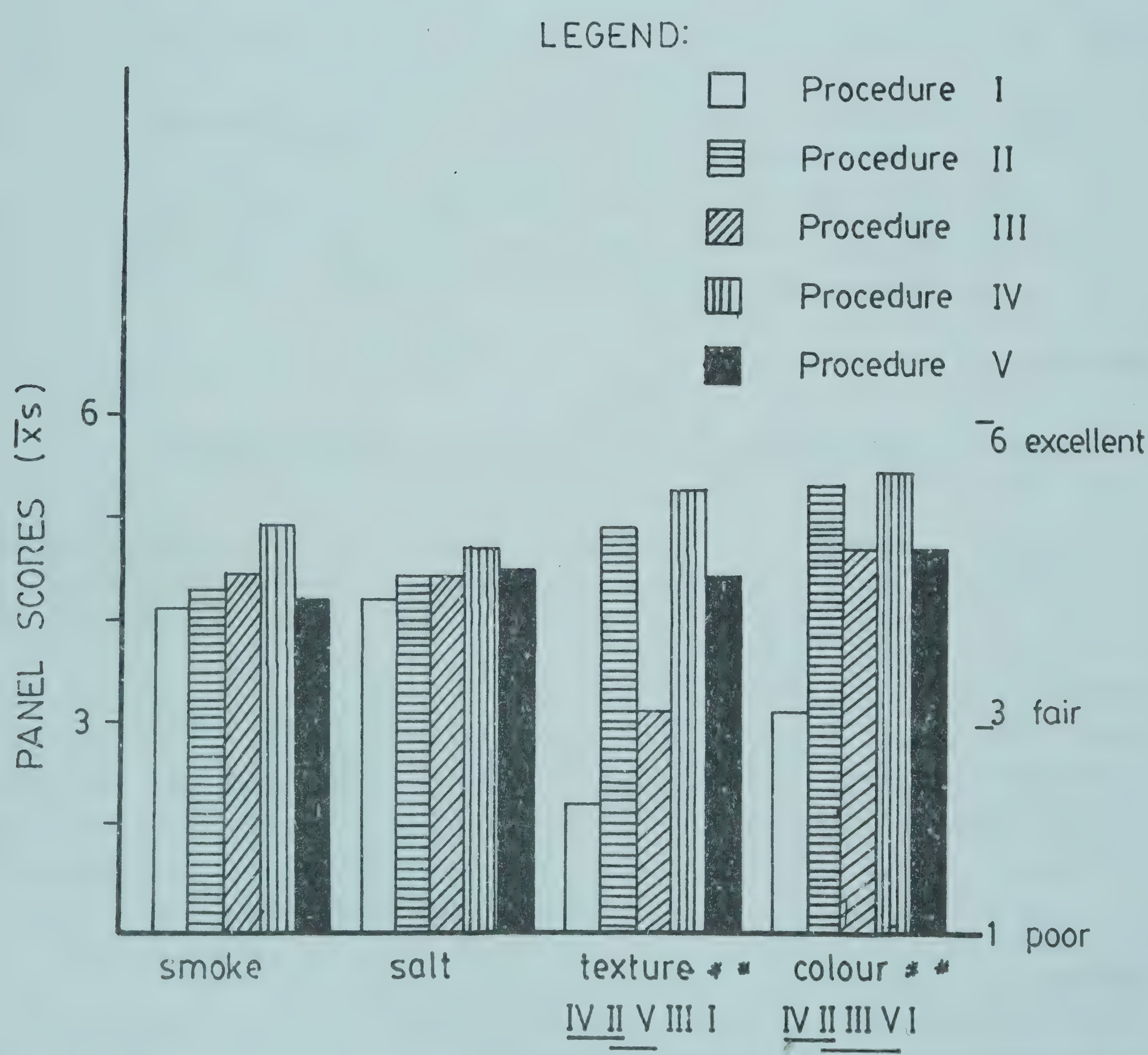
____

3. Results and discussion

3.1 Effect of different smoking time-temperature combinations on acceptability

The different smoking procedures used did not significantly affect the salt and smoke flavour of the fillets (Figure 2). However, variations were observed in texture and colour, and these resulted in significant differences in overall acceptance of the product (Table 2).

Figure 2 Effect of different time-temperature combinations on acceptability of smoked Spanish mackerel



(**) denotes difference at 1% level; samples connected by straight line, no significant difference

Table 2 Mean panel scores of Spanish mackerel smoked at different time-temperature combinations

Attribute	Procedure I	II	III	IV	V
Smoke flavour	4.1	4.3	4.4	4.9	4.2
Salt flavour	4.2	4.4	4.4	4.7	4.5
Texture	2.2	4.9	3.1	5.3	4.3
Colour	3.1	5.3	4.7	5.5	4.7
Overall acceptance	3.4	4.8	4.2	5.1	4.4

The product smoked at 45°C for 8 h (Procedure IV) obtained the highest acceptability score. Panellists preferred a smoked fish which could be sliced smoothly and thinly like ham, and could be eaten without further cooking. The desired texture was described as tender and juicy. Samples smoked at higher temperatures were rejected due to cooked flesh as demonstrated by myotomes separating when sliced. When the temperature was increased by 10°C with 8 h smoking period (Procedure V) fillets were cooked. Similarly, 3 h at 65°C and 1 h at 80 to 83°C resulted in unacceptable products. Scores when treated statistically (Appendix 1) did not show significant differences between procedures II and IV; than II and V.

Colour evaluation of the samples refers to that of sliced and whole fillets. Panellists described the smoked products as having an attractive golden brown colour. The inside portion of the flesh was found to be slightly pink to creamy white, and translucent to opaque. It was observed that as the fish flesh was cooked, its translucency diminished. Although the samples smoked using procedure IV obtained the highest mean colour score, this was not significantly different from the score of samples smoked in procedure II. Similarly, there was no significant difference among samples smoked in procedures II, III and V.

The proximate composition of the smoked products is presented in Table 3 which shows no marked difference for all indices except in the sodium chloride content. The variation in the salt contents may be due to the different qualities of raw materials used in the experiment. It has been established that the outer layer of the flesh controls the rate of salt penetration (Voskresensky, 1965) and that several post-mortem changes take place in fish altering the chemical composition of the flesh (Eskin et al., 1971; Amlacher, 1965). One of these is the decrease in water binding capacity of fish muscle due to changes in its protein structures, a phenomenon which is intensified after rigor mortis has terminated. It is said (Voskresensky, 1965) that during this period, post-rigor, salt uptake in fish muscle is faster.

Table 3 Proximate composition table of Spanish mackerel smoked using different procedures

% Composition	Procedure				
	I	II	III	IV	V
Fat	1.38	1.37	1.34	1.37	1.38
Protein	24.02	24.05	25.98	24.96	25.36
NaCl	2.67	3.90	4.03	3.96	4.00
Ash	1.68	1.98	2.28	2.31	2.15
Moisture	69.00	69.00	67.00	68.00	67.00
A_w	0.94	0.95	0.94	0.94	0.93

The salt contents in the samples which ranged from 2.67 to 4.03%, however, did not affect the acceptability of the products. The salt levels were considered by the panellists to be just within the acceptance limit.

Moisture contents of the smoked products ranged from 67 to 69%. It seems that the different procedures had no significant effect on the extent of dehydration. The same observation can be said of the water activity (A_w) of the samples. Products with an A_w range from 0.94 to 0.95 will spoil unless the storage temperature is reduced.

3.2 Changes during processing at 45°C

The internal temperature of the fillets during processing was within the range of 30 to 32°C for 6 h and reached 37°C after 7 to 8 h. These temperatures are within the optimum range for growth of mesophilic bacteria. The microbial counts are presented in Table 4. Qualitatively, these organisms were survivors of the smoking process and contaminants from the brine and sawdust used (Shewan, 1949; Bain et al., 1958a,b). Spores of pathogenic organisms were absent from this product.

For this particular species, histamine, a toxin produced through decarboxylation of free histidine abundant in the fish muscle of scombroid species, is considered to be the major problem. Outbreaks of histamine in almost all parts of the world have been reported (Taylor, 1983; Arnold and Brown, 1978).

Table 4 Changes in SPC, histamine content, and moisture content of Spanish mackerel during smoking at 45°C for 8 h

Treatment	SPC (log)	Histamine (mg %)	Moisture (%)	pH
Raw material washed and filleted	5.46	1.30	77.0	6.30
Brined (30 min in saturated solution)	4.81	1.41	70.0	6.25
Smoked	4.53	1.85	68.0	6.26

As shown in Table 4, histamine formation was minimal during processing although the smoking temperature was within the optimum range for histamine production. Washing, filleting and brining reduced contamination by histamine forming bacteria.

Moisture content of the samples decreased during processing as shown in Table 4. After brining, a 9% reduction occurred and a further 2.8% after smoking. Moisture loss is faster during brining for 30 min than during smoking (with fixed air velocity of 0.9 m/sec) inside the Torry Kiln for 8 h. The pH of the samples did not change markedly during the entire smoking process (Table 4).

3.3 Economics of production

Table 5 presents the per cent yield of raw material used. Based on 100 kg of whole fish, yields were as follows: 40 to 48% were obtained as fillets suitable for smoking; 35 to 40% suitable for human comsumption and the remaining 17 to 20% utilisable as animal feed. Weight losses incurred during processing are given in Table 6. The processor has the option to buy the fish whole or butchered (with head, gut and tail removed). There is always a ready market for the heads for human consumption as these can be cooked with vegetables for local dishes. After smoking, the yield ranged from 40 to 48% depending on the quality of the raw material. Since the procedure involves filleting, deboning, and skinning, it is recommended to use fresh fish as firmer flesh will result in higher yields.

Table 5 Per cent yield of raw material for smoking Spanish mackerel

	% yield from whole fish
Fillets for smoking	40 - 48
Recoverable as human food	35 - 40
Waste/animal feed	17 - 20

The cost of the fish ranges from ₱ 30 to 75 (US$1.5 to 2.5) per kg in Metro Manila and is lower in the provinces where it can be purchased for ₱ 18 to 25 (US$0.90 to 1.25) per kg. For production of 100 kg of smoked fish 20 to 25 kg salt is required for brining.

Table 6 Percentage weight loss of Spanish mackerel during the processing stages

Process	Weight (kg)	% Weight loss
Raw material (whole fish)	100.0	
Head, tail and gut	70.0	30.0
Skin and bones off (filleted)	52.3	47.7
Trimmed (dark meat and belly portion off)	47.7	52.3
Brined (30 min in saturated solution)	45.8	54.2
Smoked	39.2	60.8

Table 7 shows an estimate of the production cost of smoked "tangigue" using a fully mechanised smoke house. Fillets can be vacuum packed or conventionally packed using medium density polythene. Results have shown that vacuum packaging did not extend the shelf-life of this product stored at refrigeration temperature (Trinidad et al., 1986).

Table 7 Production cost* of smoked Spanish mackerel using a Torry Kiln**

	Amount (US$)	Total (US$)	Cost/kg (US$)
Raw material (100 kg)***	150.00		
Salt	2.50		
Smoking	10.35		
Packaging			
Vacuum	29.50	204.35	5.11
Non-vacuum	12.00	192.35	4.81

* excludes labour and other incidental costs

** approximate cost = US$ 10,000

*** whole fish

4. Conclusion and Recommendations

This study established smoking temperatures of 35 to 45°C as ideal for producing acceptable smoked Spanish mackerel. However, from the food hygiene point of view, it is recommended to use 45°C for 8 h.

There was a small increase in the histamine content during brining and smoking. It is therefore strongly advised to start with a good quality raw material and prevent contamination all throughout the production. Fish must be kept at refrigeration temperatures throughout the preparation, distribution and subsequent storage.

5. Acknowledgement

The authors wish to thank Mss. Lani de la Cruz and Mar Alcasid, and Mr. Cheryl Lalugan for their assistance in the preparation of this paper.

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APPENDIX 1

ANOVA tables of acceptability scores of Spanish mackerel smoked at five different time temperature combination.

A. Smoke Flavour

Source of variation	df	SS	MS	f
Samples	4	5.56	1.39	1.38
Panellists	14	9.29	0.66	0.65
Error	56	56.44	1.10	
Total	74	71.29		

B. Salt Flavour

Source of variation	df	SS	MS	f
Samples	4	1.81	0.45	0.54
Panellists	14	11.68	0.83	0.99
Error	56	46.99	0.84	
Total	74	60.48		

C. Texture

Source of variation	df	SS	MS	f
Samples	4	77.27	19.32	35.13**
Panellists	14	8.17	0.58	1.05
Error	56	30.73	0.55	
Total	74	116.17		

IV	II	V	III	I*
5.3	4.9	4.3	3.1	2.2

D. Colour

Source of variation	df	SS	MS	f
Samples	4	55.15	13.79	25.07**
Panellists	14	8.58	0.62	1.13
Error	56	30.85	0.55	
Total	74	94.58		

IV	II	V	III	I*
5.5	5.3	4.7	4.7	3.1

Note: Means of samples connected by a common line showed no significant difference.

* denotes significance at 5% level and ** at 1% level

DEVELOPMENTAL ASPECTS OF VILLAGE BASED FISH PROCESSING METHODS IN SIERRA LEONE, WEST AFRICA AN APPRAISAL OF SOME TECHNICAL, SOCIAL, ENVIRONMENTAL AND ECONOMIC FACTORS

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1. Introduction

The goal of the Fisheries Pilot Project Tombo is the promotion of the integrated development of artisanal coastal fisheries in Sierra Leone and is jointly financed by the Republic of Sierra Leone and the Federal Republic of Germany. The Project was established in 1980 and the present phase will continue until 1987.

The integrated approach is a multi-sector development method involving various technical elements of the artisanal fishery and social and community development aspects of the fishing villages. For this approach to be effective, participation and support must come from all elements of the fishing community.

The Project promotes development in the following areas:

1.1 Fisheries technology

Fishing gear technology, boat building, fishing crafts' propulsion, marine engineering, fish handling and processing, marketing of fish.

1.2 Infrastructure and community development

Development and promotion of self-help groups, co-operatives etc., - development of village administration, development of sanitary infrastructure (water supply dam, pipe borne water supply system, pit latrines, waste disposal), primary health care (construction of health centre, primary health education).

The Project entered a stage of becoming a parastatal self-financing National Fisheries Development Agency (NAFDA) - Model. It generates funds through the importation and retail of fishery equipment to co-operatives.

Returns are sufficient to finance major operations and programmes of the Project with little financial input from the Government of Sierra Leone.

Women play an important role in the West African small-scale fishery, dominating fish processing and marketing. Marketing activities of the "fish mammies" often extend beyond national boundaries. In 1961 the Project developed a program on the role of women in fishes (Kotnik, 1982a).

Any effort to further develop and improve fish processing methods in West Africa must carefully take the existing social structure into account. The existing chain of "fish catching - handling - processing - and marketing" provides an economic and social cohesion of all members of this industry.

The purpose of this paper is to describe important technical, social, environmental and economic factors in the fish processing link of this chain. The paper also stresses the necessity of approaching small-scale fisheries development not only technically but from an interdisciplinary, integrated point of view. "Technical problems" can have underlying social causes which may become development bottlenecks if not perceived and carefully considered in the planning of programmes.

2. Climatic outline and fishery profile of Sierra Leone

Sierra Leone has 570 km of coastline extending from 7 to 10^{o} north latitude on the East Central Atlantic. This coastline is shaped by numerous estuaries in which wide mangrove zones dominate. The shelf is about 24,800 sq km (140 km width at the northern border, 32 km width at the southern border). A coastal map of Sierra Leone is shown in Figure 1.

Sierra Leone is tropical with a dry season between November and April, and a rainy season between May and October. Annual precipitation ranges from a (coastal) value of 4,000 to 7,000 mm to a (hinterland) low value of 2,000 to 3,500 mm. The humidity is high throughout the year, except during the period of North East Trade Winds (Harmattan which occurs in December and January. The mean annual temperature is 25.3 to 26.8^{o}C depending on the location.

There are 20,000 fishermen in 550 villages on the coast of Sierra Leone operating some 5,500 open wooden fishing crafts:

- paddled dugouts, 4 to 6 m l.o.a.
- paddled or sailed planked canoes, 5 to 8 m l.o.a.
- motorised planked transom canoes, 7 to 11 m l.o.a.
- motorised planked double-end canoes, 13 to 19 m l.o.a.

Annual production from the coastal artisanal fishing activities is about 35,000 t, which is locally consumed. More than 100,000 t are caught annually by foreign vessels (mainly from the USSR). Because the Sierra Leone currency is not freely convertible, the bulk of the industrial catches are not landed in Sierra Leone, but transshiped and sold elsewhere against freely convertible currencies.

3. Traditional handling and processing methods

3.1 Social structure of the fish processing Temne family at Tombo

There are 11,000 villagers at Tombo. The population at Tombo is composed of four main tribes (Temne, Sherbro, Fullah, Krio) with male-female role differentiation schemes. Family structure varies from tribe to tribe. In 1981 seventy seven per cent of the Tombo population were Temne (Kotnik, 1981), the dominant tribe in fishing activities.

Temne households are extended families. The hosuehold size varies from 25 to 120 members. They are Muslim and polygamy is a common practice. Family heads can obtain wives without consulting their spouses. Family leadership depends on the principle of primogeniture: the eldest son becomes head of the household. He is the arbiter of social and economic questions or issues which arise. A household often consists of several family units.

The women of the household are a "workforce" which engage in various economic activities under the supervision of the first wife of the head of the household. At the end of the year the first wife declares business profits to the head of the household who may be her husband or, if he is dead, her husbands eldest son. The senior wife of a deceased head of the household retains her command over the household, and over the female business until she dies. Even the senior wife of the new family head and his other wives are under her authority. When a head of household dies the junior wives leave the household, to re-marry, or to rejoin their original families.

Fish processing and marketing in the small-scale fisheries of Sierra Leone, as elsewhere in West Africa, are handled by women. In a Temne fishery household the following division of labour is generally observed:

- The head of the household is the owner of one or more fishing boats, organising the work of several tens of fishermen. He is responsible for operations, maintenance of gear, boat, engines and the sale of fish landings.

- The boatowner or his senior wife organise the sale of the landings at the beach. Frequently the senior wife is also a buyer and processor of fish from her husband or from other boat-owners, in which case she

oversees the processing of her fish. She also takes part in the raising of children of her household. The junior wives work under the supervision of the senior wife in the processing and marketing of fish. They rarely make independent decisions, and are usually not paid for their labour. The senior wife is responsible for their needs and needs of their children. Junior wives sometimes obtain small loans from the senior wife or the head of the household to set up small business enterprises, from which they are allowed to realise profits.

3.2 Pre-processing handling

The fish processing method described are employed in a small-scale fishery equipped with a fleet of 18 m planked canoes powered by 25 or 40 h.p. outboard engines and some diesel inboard powered boats developed by the Tombo Project. The fishing gear is an encircling ringnet of about 800 m length and 35 m depth. Twine size is 21 od/9 and the stretched mesh size is 3.81, 4.13, 4.44 or 5.08 cm. Fishing is in daytime. Shoals are lookout-spotted and the net is shot around the shoals of Sardinella maderensis or Ethmalosa fimbriata. The encircled fish are gilled, entangled or pursed. The average catch composition of the ringnet fishery at Tombo is:

- 47% weight Sardinella maderensis (madeiran sardinella, "Herring")
- 43% weight Ethmalosa fimbriata (Bonga shad, "Bonga")
- 10% weight Scomber japonicus (Chub Mackerel, "Mackerel")
  Pseudotolithnus spp. (Croakers, "Lady")
  Sphyraena spp. [Barracudas, "Kuta" (ad.), "Kinni" (juv.)]
  Ilisha africana (West African ilisha, "Lati")
  Selene dorsalis (African lookdown, "Cutmoney")
  Ariids (Catfish), Pomadasyids (Grunts) and others

It requires an hour or more to haul the net, which is pulled over the gunwhale of the boat, damaging gilled fish. While the net is hauled, easily removable fish are taken out of the net and dumped into the bilge, which contains salt water, mud, rotten fish, petrol, engine oil and trash. The sodden net with many gilled fish lays in heaps in the bilge and on the thwarts of the fishing crafts. While returning to Tombo, a 1 to 3 h voyage, the crew occupy themselves with the task of clearing the net of gilled fish. The fish are removed by squeezing the posterior, forcing them through the mesh. The cleared fish are dumped in the bilge. During this period the catch is exposed to direct sunlight.

The boats try to return to Tombo at high tide so that they have enough water to land at the beach. At low tide shallows extend hundreds of meters out from the beach. The presence of a low tide can force a boat to stand offshore for hours, exposing the already abused catch to the degrading effects of sunlight in a hot, filthy bilge.

The catch will not be landed at the beach until the net is cleared. This is done to avoid pilferage at the crowded landing beach. After the net is cleared, the fish are washed inside the boat with seawater and carried to the beach in metal head-pans and dumped into a heap on the beach.

The catch is sorted by species and roughly graded by size. The fish are counted in dozens by members of the fishing crew or professional counters attached to the boatowner's household.

The process of a more-or-less free market determines the price. If landings are large, the price is low. If landings are scarce, the "fish mammies" bid the prices up. Late landing boats sell at the lowest prices, and are often obliged to sell on credit. Arrangements for payment depend on the boatowner-processor leadership. Fish is often given on credit, with a later reconciliation.

Because the fish processors buy fish from more than one boat, much of the catch lies on the open beach for hours. The fish are washed once again on the beach with seawater by junior wives and their daughters. The fish is then transported in head-pans to the drying platforms (bandas) of the "fish mammies". These bandas are located inside their compounds.

The time lapse between the hauling of the net and the commencement of the fish smoking ranges from 7 to 10 h and is composed as follows:

- hauling of the net	1.0 - 1.5 h
- clearing net and return home	1.0 - 2.0 h
- discharge fish, count and sell	1.5 h
- washing by processor	1.0 h
- transport fish to Banda	1.0 h
- lay fish on Banda	1.5 - 2.0 h
	7.0 - 10.0 h

3.3 Fish processing methods

3.3.1 Heat-drying of herring and bonga on bandas

3.3.1.1 Technique

In West Africa, platforms which suspend fish over smoking fires preserve the catch. These platforms, known colloquially as bandas, range in size, shape and sophistication (Figures 2 and 3). Bandas in Tombo are rectangular in form and vary from 4 to 25 sq m of surface area.

Mud blocks, stones or scrap sheet-metal form walls to a height of 50 to 70 cm around a shallow rectangular fireplace. Suspended over the fireplace

are drying racks of metal grating. Wooden poles or metal pipes sunk into the earth around the walls of the fireplace support the drying rack.

This banda design is known as Fante banda. It was introduced by migrating Ghanaian fishermen (Fante tribe) who came to Sierra Leone around 1950 (Figure 3).

The fireplace walls of the traditional Sierra Leonean banda are open, with a platform of closely spaced bush sticks (Figure 2). These open bandas are still in use in fishing villages all over Sierra Leone.

Tombo processors adopted the Fante banda for the following reasons:

- unlike many subsistence fishery villages, Tombo has a small-scale industrial character, with a high production potential which requires efficacy

- the Fante banda consumes less firewood than the traditional open-walled design, reducing processing costs

- relatively small fish (herring and bonga) are dried by processors in Tombo. The closed-wall metal grate design contains the small fish, and of course last much longer than the bush stick platform in the high temperature generated in the industrial sized banda at Tombo.

The capacity of the Fante banda in use at Tombo varies from 200 to 1,600 dozen herring. Washed fish are neatly laid on the surface of the banda by professional fish layers or by members of the household of the fish processing wife. The ventral tips of the body rests on the wire grating with the dorsal fin up as shown in Figure 4. When the platforms must be more closely packed, the ventral tips of the operculum rests on the wire grating with the tail fins tilted about 30^{0} into the air. Two or more people are usually employed in the fish laying process which lasts between 1.5 and 2 h for 400 to 500 dozen of herring.

Wood is arranged in the fireplace and doused with kerosene and set alight. Much heat is required during the initial stage of drying because quick sterilisation in the early stages is essential (finished product dried and partially cooked). Constant attention for 3 to 4 h is required. Wastage of 15 to 75% was reported by Walter-Dehnert (1981). After the initial stage of 3 to 4 h of relatively intense heat, the fire is reduced to smoking embers over which the fish remain for another 1 to 4 h. The fish are then cooled for several hours. This product is known as fresh-dried fish, and will have lost about 40% of its fresh weight.

Most fresh-dried fish are sold in nearby markets and are usually consumed within 48 h, as the shelf-life is only between 2 to 4 days.

For a hard-dried product, the fresh-dried fish are turned over after cooling. The dorsal side then rests on the grating for re-smoking for another 2 to 5 h over low heat. The hard-dried product has lost about 65% of its fresh weight.

After cooling, the fish are separated, sorted, counted and packed in baskets or boxes for transport to local or hinterland markets. Baskets can contain between 400 and 600 dozen herring or 200 to 300 and 20 dozen of bonga depending on size. Records of shelf-life of 3 weeks during the rainy season and 8 weeks during the dry season have been made (Kotnik, 1982a).

Bonga has about three times commercial value of herring. Juvenile bonga ("Awefu") are hard-dried for the provincial market. Large, mature bonga, which are seasonally caught at Tombo, are fresh dried for 4 to 5 h and sold in nearby markets and in Freetown. Fresh-dried bonga retain most body fluids and have a shelf-life of 2 to 4 days.

Fante and traditional bandas show the following limitations:

- They waste energy. Most of the heat and smoke passes through the single layer of fish and is only partly used.

- The fish must be turned over before hard-drying, resulting in breakage.

- Improper control of the fire often results in charring leading to losses as high as 30%.

- The 4 to 16 h of close attention to successfully heat-dry fish is stressful for the processors.

- Open bandas are usually under cover or in smoking houses where processor families spend many hours breathing smoke-polluted air. It is an unhealthy environment. During windless nights the smoke of about 200 bandas at Tombo is so heavy that the whole village, accommodating 11,000 people, is pervaded with smoke.

- Frequent repairs and major annual renovation are required.

- Banda enclosure lack storage space. Maggot infestation before packing for market transport is common.

- Thievery is common because of insecure enclosures and intensely crowded living conditions at Tombo.

3.3.1.2 Firewood supply

Firewood for the bandas at Tombo is supplied by local Fullah or Temne wood cutters. The wood cutters fell trees in nearby private forests. Unsplit felled timber is also supplied to wood cutters from Government forests of the Freetown Peninsula (officially and unofficially). Wood cutters work 12 to 16 days spread over a month to produce "one trip", which is two cords of splitwood. "One trip" is 5.7 cbm timber.

The production costs of one trip of firewood from the forest to the selling stall at Tombo are shown in Table 1. The prime cost of 5.7 cbm of split firewood is presently Le 282.- if the wood cutter splits the wood himself, and Le 412.- if he employs somebody to do the splitting. Three thousand twenty four units of split wood of about 1.9 cbm each are contained in 5.7 cbm (2 cords). Four unit pieces of split wood were sold for Le 1.- in January, 1986. Hence, 5.7 cbm produced at Le 282.- respectively Le 412.- prime cost should be sold at approximately Le 757.- .

Wood species used for smoke-drying of Sardinella maderensis and Ethmalosa fimbriata at Tombo are shown in Table 2. About eighty-five volume-per cent of this timber recorded in January, 1986 consisted of Parinari excelsa (Rosaceae), Daniella thurifera (Caesalpinaceae), Ochthocosmus africanus (Ixonanthaceae), Xylopia aethiopica (Annonaceae), Carapa procera (Meliaceae) and Xylopia quintasii (Annonaceae).

The species preference of twelve species of firewood - forming about 96% of the supply in January, 1986 - by thirty eight interviewed firewood cutters at Tombo is shown in Table 3. The species preference for the same 12 species of firewood by 42 fish smoking women at Tombo is given in Table 4.

The weight of firewood to heat-dry herring or Bonga on Fante-type bandas is about 30% of the weight of the fresh fish to be dried. Some 7,500 t of fish are landed annually at Tombo, indicating that the weight of firewood burned annually is in the range of 2,250 t or 2,700 cbm. The high demand for banda firewood at Tombo is the cause of heavy deforestation and subsequent soil erosion around the village. Investigations are now underway to quantitatively assess the effect of firewood cutting on the forests in this area. This study is especially important for the Project because the presence of the Project at Tombo since 1980 has led to:

- an increase of large locally based open wooden fishing boats from about 40 in 1980 to 80 in 1986; hence to an increase in landings and in heat-dried fish,

- an increase of the Tombo population from about 6,000 to 10,000; hence, to an increased consumption of firewood for cooking.

3.3.1.3 Economics

3.3.1.3.1 Cost of construction and maintenance

Bandas are simple in design and require few skills to construct. Wire grating and iron or steel pipes must be obtained from Freetown (some 30 miles distant), but other materials are locally available and inexpensive or free.

A banda with a capacity for 600 dozen of herring costs about Le 700.- to build, most of which is spent on wire gratings, chicken wire, and iron pipes.

Chicken wire burns through quickly and needs replacement every 3 to 6 months. Iron pipes are expensive but can last up to 5 years. Wood poles can be used instead of iron pipes to support the platforms but they burn quickly and must be replaced every 2 weeks. According to 1986 surveys a banda lasts up to 5 years, with a monthly repair cost of Le 50.- to 150.- and an extra annual overhaul cost of about Le 300.-. Hence, between 900.- and 2,000.- Leones have to be spent for repairs annually.

3.3.1.3.2 Processing costs

Processing costs are the costs of fuel wood, kerosene, labour and banda repairs.

3.3.1.3.3 Herring

A breakdown of processing costs for 600 dozen of herring is given in Table 5. Six hundred dozen of herring, weighing 543 kg, were bought at Le 0.70/dozen being Le 420.-/600 dozen. The processing costs for fresh-dried herring were Le 51.- (being 12% of the value of the fresh fish) and Le 74.- (being 18% of the value of the fresh fish) for the hard-dried product. Hence, the prime costs, excluding depreciation and maintenance costs of the banda as well as family labour costs, were Le 0.79/dozen for fresh-dried and Le 0.82/dozen for hard-dried herring.

3.3.1.3.4 Bonga

A breakdown of processing costs for 150 dozen of bonga is shown in Table 6. One hundred fifty dozen of bonga, weighing 300 kg, were bought at Le 6.00/dozen, being Le 900.-/150 dozen. The processing cost for fresh-dried mature bonga were Le 29.50, being 3.3% of the value of the fresh fish. Hence, the prime cost were Le 6.20/dozen.

Sales prices at Tombo fluctuate depending on supply and demand. On average the price of hard-smoked herring is presently between Le 1.50 and Le 1.80 per dozen. Prices for heat-dried bonga range between Le 9.- and Le 12.- per dozen.

3.3.1.4 Labour

Junior wives and daughters carry the firewood from the wood cutters at Tombo to the processing compound while the senior wife is responsible for the payment for the wood.

The laying of fish on the banda is done by junior wives and children or by professional layers/packers. These packers are mainly teenage boys and they receive a renumeration for their work.

The laying of the wood is done by subordinate family members. It is a stressful work and involves crawling through the fire hole beneath the banda platform. The fire is tended by the senior wife, junior wives and daughters. Junior wives, children or professional layers turn the fish before the second heat-drying takes place.

Occupied by one chance or another, women and children often remain around the banda throughout the night, while processing is occuring.

After processing, the fish is sorted by size and packed either in baskets (up to 450 dozen of herring or 300 dozen of bonga) or in wooden boxes (500 dozen of herring or 300 dozen of bonga).

It is the responsibility of the buyer to provide baskets, boxes and labour for the packing. The packing is often done by professional packers who are often teenage boys. The packing of the fish is done very neatly to avoid breakage during the transportation of the baskets and boxes over long distances on bad roads. When packed fish is sold to another buyer, it is removed from its container and re-counted. Re-smoking of the fish on its way to the consumer may be necessary and is then carried out by the fish trading woman.

3.3.2 Sun-drying and salting

3.3.2.1 Sun-drying

The West African ilisha (Ilisha africana) locally known as "Lati" and the Atlantic bumper (Chloroscombrus chrysurus), locally known as "Cutmoney", form a substantial portion of local beach seine catches and are by-catch on a seasonal basis in the encircling ringnet fishery. Both species have relatively low commercial value and are processed for distant markets, away from the coast. Both species have a small, deep and compressed body, which favors processing by sun-drying.

In the sun-drying methods, fish are scattered to dry on a bare floor or a mat during the day and stored in a sheltered place at night. The best processing results are obtained during the Harmattan (dry North East trade winds from the Sahara desert). The sun-dried fish are finally cold-smoked to

give them a smoky flavour and texture. The sun-dried/smoked fish usually contain sand particles and grit picked up while drying on a dirty or sandy surface.

3.2.3.2 Salting of fish

In Sierra Leone the uncertain availability of cheap salt in sufficient quantities blocks the widespread use of preservation by salting. Locally manufactured salt is not available in large quantities, and imported salt is high priced.

Salted fish is not a traditional food throughout Sierra Leone. Its consumption is limited to Freetown and coastal villages where it is used to flavour soups. Between 1940 and 1960 large locally produced surpluses of fish were preserved by salting, giving impetus to wider acceptance of the product. Fish commonly preserved by salting were seabreams, croaker, grunts, mackerels, catfish and ladyfish. A further impetus to acceptance were at that time inports of salted-dried cod (klipfish) from Norway.

At this time there is very little fish preservation by salting in Sierra Leone. It is still used in one interesting local fishery, however. The "Benefit Boat Fishery" presently is carried out by two boats only in Sierra Leone. The Benefit Boat is a 3 to 4 men planked sailing canoe with transom and fixed rudder. Benefit boats have long voyaged out of the Freetown Peninsula to fish with longlines and handlines, often for a week at a time. These boats were equipped with portable smoking units. When catches are large, fishermen resort to salting to preserve their fish at sea.

On-board the Benefit Boat, the fish are scaled, gutted, and split from the head to the fore-portion of the caudal fin on the ventral side. Salt is rubbed into the fish and then placed in layers in a container. Between each layer of fish are layers of salt and leaves of the Coco Yam (Colocasia esculenta). It is claimed by fishermen that these leaves help the curing process. Water drawn from the fish by the salt settles in the bottom of the container. At frequent intervals the fish are re-stacked, the top layers going to the bottom and the bottom layers to the top. This produces an even cure. The period of time the fish is in contact with salt is known as the "rousing time" which lasts until just before the fish is landed. The fish is then rinsed with seawater before landing.

4. Fish processing methods introduced to Tombo by the Fisheries Pilot Project Tombo

4.1 Chorkor smoker

4.1.1 Technique

The Chorkor smoker derived from the "Ivory Coast" kiln (Figure 5) which was a square smoker built of adobe bricks or scrap sheet metal (metal sheet flattened from big fuel drums) equipped with heat vents regulated by dampers, and a metal sheet heat spreader with large perforations which is hung over the fire. Using racks of light-weight metal grill affixed to wooden frames, several layers of fish on stacked frames can be smoked and dried at the same time, the top-most frame being covered with a dampened hessian cloth.

Small-scale fishing communities in Ghana drew on this model to develop the Chorker smoker. Particulars on the introduction of the Chorkor smoker, its construction, and its use in the Gulf of Benin (West Africa) are given by UNICEF (1984).

Prototype Chorkor smokers were built in Sierra Leone by the Shenge Region Fisheries Project and by the Fisheries Pilot Project Tombo. Construction and technical details of the Tombo-type Chrokor smoker are shown in Figure 6.

The Chorkor smoker built at Tombo is operated with an optimum of 3 trays stacked on top of each other. The fires are set in a pit in each chamber of the oven, the base of which is about 15 cm below ground level. The flame is 35 to 50 cm below the bottom drying frame. As with the banda, the initial drying process requires intense heat and the fire has to be closely watched to avoid damaging the fish or the frames. The temperature is controlled by removing wood or sprinkling the fire with water or by adding wood. The final stage requires only low heat, with sawdust and wet wood added to the fire to produce smoke, this is done to improve the flavour of the fish.

During the drying cycle, the vertical sequence of trays is changed 2 to 4 times to more equally disperse heat. Sometimes the trays are rotated horizontally as well.

Fresh-drying of herring takes about 3 h and 19% of the fresh fish weight is needed as firewood to yield a fresh-dried product. Fresh-drying of bonga takes about 5 h and 22% of wood is required. A comparison of drying times and firewood consumptions of Sierra Leone-type bandas, Fante-type bandas, Chorkor smoker and Altona oven is shown as in Table 7.

4.1.2 Economics

The Chorkor smoker is relatively simple to construct and the capital investment is about Le 665.- for a Chorkor smoker with 3 chambers and a drying capacity of about 342 dozen of herring (315 kg fresh fish weight).

According to UNICEF (1984) the wooden frames of the trays can last as long as 3 years and the wire nets for 2 years if the trays are properly constructed and maintained. On the other hand, preliminary experience with the Chorkor smoker at Tombo indicates a much lower life span of frames and wire mesh, possibly because drying operations at Tombo have an industrial character of mass production.

4.1.3 Labour

The pattern of labour in the operation of the Chorkor smoker is different from that of the Fante and traditional bandas. Effective Chorkor drying entails vertical and horizontal turning of drying frames. Each Tombo Project model drying frame will contain 38 dozen herring, weighing some 35 kg. For a 3 chambered, 9-frame Chorkor smoker, 38 dozen/frame x 3 frames/chamber x 3 chambers = 342 dozen fish must be layed per drying cycle. Each tray will be turned once, and will be vertically moved twice. Though these manipulations of Chorkor drying frames are an element of labour not present in the operation of bandas, the trays are light and easily handled. In summary, there is little, if any, additional labour requirement to operate a Chorkor smoker as compared to a Fante or traditional banda or an Altona oven.

4.2 Altona ovens

4.2.1 Requirements

The Altona oven was first introduced to Africa in Nigeria (Figure 7). Since that time its acceptance has been tested in other countries in West Africa, unsuccessfully. It is said that the high construction cost discourage acceptance.

The Fisheries Pilot Project Tombo developed an Altona-type oven in Tombo (Figure 8) at the request of processors (women) in improving heat-drying techniques. It was designed to meet the relatively high production requirements of the quasi-industrial processing operations at Tombo.

The Project's Co-operative Women's Society participated from an early stage in designing this oven. Their requirements, as given in Kotnik (1982b) were:

- wood consumption must be much less than that of the traditional banda

- low maintenance requirements

- labour inputs per unit of production should be significantly less than that required for banda operations

- productivity should be at least as great as that of bandas

- the laying procedure should be similar to that of the traditional banda; i.e., for rapid laying of fish of similar size

- construction material should be available in Tombo or Freetown

4.2.2 Technique

The Tombo Altona-type ovens (Figures 8 and 9) consist of a drying chamber mounted on a firebox. Both elements were constructed from fired bricks that were available from brick factory in Freetown. Other materials used were strong wire mesh for the baskets/trays, metal hinges, box pipes, cement and flattened metal sheets from old oil drums.

The drying chamber can contain 16 wire mesh drying baskets (122 x 75 cm) which rest on ledges of turned bricks (Figure 8) or on steel rails of a complete steel insert frame (Figure 9). The oven has a concrete roof and a chimney with draft control.

The oven is pre-heated while fish are laid on drying baskets. The mode of laying is the same as on bandas. When two rectangular baskets are filled with closely packed fish they are placed in the lowest position in the oven. The oven is then closed and two more baskets are prepared. This allows fluids to initially drain from the fish. This process continues until 16 frames are filled and placed in the oven, at which time the top pair of baskets will have been in for the longest period of time, and the bottom pair for the shortest period.

The Tombo Altona-type oven was designed to avoid the relatively large temperature gradient from the bottom to the top baskets found in other models. This was achieved by leaving space between adjacent fish-covered baskets through which heat and smoke pass freely. One hundred eighty degrees centigrade were observed around the lowest and 125°C at the top baskets. To avoid burning of the fish on the lowest baskets and to ensure drying of the fish placed on the highest baskets, interchanging of the baskets during the process of drying is necessary.

4.2.3 Economics

Construction cost of the Tombo model Altona oven is at present about Le 5,000.-, which is equivalent to almost US$1,000 according to the official rate of exchange.

Cost of maintenance are negligible and due to the strong structure of the Altona oven, the durability should be well over 5 years.

The wood consumption for the first drying process of herring is only 13% of the fresh fish weight dried. This is only 33% of the firewood consumption of the Sierra Leone-type banda, 43% of that of the Fante-type banda and 68% of that of the Chorkor smoker.

The smoking time to produce a fresh-dried herring product is about 2.5 h, hence, the Altona oven smoking time needed to produce a fresh-dried herring product is 56% of that of the Sierra Leone banda, 63% of that of the Fante banda and 83% of that of the Chorkor smoker.

Further comparison are shown in Table 7.

4.2.4 Labour

The deployment of labour for Altona oven processing is different from that of the Fante and the traditional bandas. In standard Altona oven designs, drying frames or baskets can hold as many as 62 dozen herring, weighing 56 kg depending on the size of the herring. There is much handling or loaded baskets, requiring more physical strength than for the banda processing operation. For the 16 trays (1,000 dozen herring capacity model) 16 separate fish laying has to be done and the trays have to be moved a total of 72 times; 56 of which when the trays are hot. This rotation of trays changes the traditional labour demand structure; stronger women or men are required to carry out this tray rotation process. The Altona oven dried fish, once locked inside the oven, does not need constant watch during the process of cooling since it is there well secured against theft. Infestation by flies is minimal as long as the fish is kept inside the closed oven.

5. Development aspects

5.1 Introduction of Altona ovens to Tombo

FPPT advisors and the fish processing women at Tombo mutually recognised the disadvantages of banda heat-drying and discussed ideas for improved processing techniques (Kotnik, 1982a).

It was clear that the cost of solving the problems associated with banda processing was too great to make it worthwhile to improve the banda. The introduction of Chorkor smokers as an intermediate step between the banda and a closed heat-drying device was considered. But the idea was rejected because the Chorkor's small capacity would not meet the requirements of semi-industrial or industrial fish processing as carried out at Tombo.

The fish processing women agreed with the Project proposal to develop an Altona-type oven that would meet the requirements of the fish processing community. The ovens were constructed in 1981 and 1982. THe cost of construction of the Altona oven was at that time about Le 1,200.

At that time there was little indication that macroeconomic conditions in Sierra Leone would drastically deteriorate, leading to persistent price inflation, with a severe shortage of foreign exchange and consequent price escalation of imported materials which has caused a 4-fold increase in cost of an Altona oven since then.

The Project provided loans to 12 members of the target group for oven construction, the loans to be repaid in installments.

The women were well trained by the Project in the use of the ovens and close communication was maintained between the women and the Project for feedback.

Of Le 14,000 loaned out, Le 10,000 were repaid. The loans not repaid were made to women who were forced to abandon their ovens because of family dissolution.

Of 8 women who frequently used their Altona ovens, only 2 abandoned their bandas. The other 6 found it profitable to operate both banda and Altona oven (increase in heat-drying capacity).

No fish processor has built an Altona oven with her own money in Tombo. Their willingness to build and use Altona ovens has always been linked with a requirement of Project loans to fund the cost of construction.

Subsequent to the original loan program, the Project decided not to provide loans unless the processor is prepared to provide at least 50% of the cost of construction. Meanwhile, the persistent price inflation and the unavailability of imported construction materials are other factors which slowed this programme.

The Project did develop a simple mud block Altona oven using locally available materials as much as possible. This led to large reductions in the cost of construction, but even so, the acceptance of this Altona oven design does not take place without external financial support in the form of grants or loans (Figures 10 and 11).

5.2 Development and acceptance factors

The economic advantage of Altona ovens are evident. In 1981 to 82, the initial investment cost for the construction of an Altona oven was about 3 times the cost of a traditional Fante banda. The reduction of operating

costs (maintenance and firewood), however, would have enabled processors to recover the higher investment cost of the Altona oven after less than a year.

That this technology did not gain sufficient acceptance, without the inducement of loans for financing construction, is a result seen elsewhere. It is likely due to complex factors, to be discussed below (see also Table 8).

5.2.1 Economic factors

The economic disadvantages of this innovation are probably not fully understood by the target group. Analysis of the cost of firewood as a per cent of fresh fish cost suggests that processors were unconvinced that it was worthwhile to invest a relatively large sum of their money for what they perceived as a relatively small percentage increase in profit. To produce fresh-dried herring, 6.7% of the cost of the fresh fish is spent for firewood, as is 9.3% for hard-dried herring. The figure for bonga processing is less than 3%. Based on possible fuel wood savings of about 60% in Altona oven processing, these figures could be reduced to 2.9% (fresh-dried herring), 4.04 (hard-dried herring) and 1.3% (bonga). Hence, a processor could save about Le 16 (fresh-dried herring) or Le 22 (hard-dried herring) when processing 600 dozen of herring in an Altona oven. These savings are small when compared with the processor's outlay for the fish (about Le 420) or with her return from sales of Le 720 to Le 900. For similar reasons the financial advantages gained from the low maintenance costs of the Altona oven, which are realised in the long-term, did not impress the fish processors. It is a characteristic of this society to undertake short-term investment at low initial costs, even in the face of strong economic arguments supporting the efficacy of a longer view with greater investment.

It became clear through Project investigations (Beck and Forde, 1985) that technical and economic failures in the small-scale fisheries sector cannot be explained solely in technical and economic terms. The traditional social relationships of boatowners with fish processing and marketing women are more complex than a simple business relationship. The system is operated through credits of goods and cash at varying prices in differing conditions and circumstances. Increased costs of production caused by inefficient business operations can be passed on to the consumer through the chain boatowner - fish mammy - wholesaler - retailer. The strong symbiosis which holds the system together, protecting the elements, also acts to remove the exigene of efficient operation. Losses occuring in one sector can be absorbed within the chain. This very flexible socio-economic system is able to accept severe economic strain.

The price of this socially durable symbiotic relationship is the support of inefficiency and backwardness, and a blindness to the long-term

value of improved operations through technology and efficient management. The close social connection between production, processing, and marketing protects each element from economic pressure so that the elements do not have to respond with improved operations to survive.

As long as the price of firewood remains at a level where processors are not seriously handicapped in processing with bandas, they probably will not feel a need to change. Thus, we can see that though the effects of depletion of readily available or nearby woodland is reflected in the higher prices of firewood which must be transported from more distant areas by lorry transport (transport costs up to 82% of the prime cost of such wood), the processors do not feel yet an economic impetus to change. It can be assumed that major changes in production methods can only be achieved if processors come under very heavy economic pressure, pressure such that the other links of the chain are unable to compensate for the losses of the processing links with profits made in other links.

5.2.2 Health and environment

The air pollution of banda smoke seriously affects all family members, especially children, who sleep around the bandas at night. There is little awareness in the processor families of the seriousness of this health problem.

Deforestation is a problem in the Tombo area. However, as long as firewood is available at supportable prices, processors are unconcerned with the issue of deforestation and consequent soil erosion. It is likely the problem will become worse.

To halt the rate of deforestation and soil erosion will require action from the Government of Sierra Leone. Because much of the thin covering of topsoil is eroded from cleared areas, exposing rock underlayment, it is evident a considerable forestry input will be required to rehabilitate the area and to secure a long-term wood supply for Tombo. Of course, further development of the production sector of the fishery will exacerbate the already difficult problem of deforestation and erosion.

5.2.3 Social factors

Community and family cohesion is enhanced by the social context in which the bandas are operated. The banda enclosure is a place where the family gathers, it is a focus of labour, a means of control of family members, in accordance with the hierarchy of authority in the Temne household.

The banda is a roofed area, a place protected from rain and sun, where communication between family members and neighbours takes place. Aside from

the promotion of family and community stability, the intimacy advanced by such an arrangement serves as a teaching function as well.

The mode of operation of the Altona oven seems to upset this social interplay. There is no roofed area around the Altona oven where people can gather and work together and pass the time in palaver. The Altona oven also seems to destabilise the traditional division of labour in the family. Its operation requires a reorganisation of traditional labour roles. The drying baskets are heavy (loaded, about 64 kg) and hot to handle, and in total there are up to 72 drying frame movements in one heat-drying cycle. This requires the labour of stronger family members than children and young women.

It also seems to be important to the women to observe their fish during processing. This cannot be done when operating Altona ovens, the doors of which are closed during heat-drying.

Although the Chorkor smoker can be considered an intermediate technology (occupying a place between the banda and the Altona oven) some of the social acceptance problems outlined for the Altona oven may also be valid for the Chorkor smoker. Up to now the Project has insufficient experience in using the Chorkor to evaluate its application for semi-industrial or industrial use at Tombo. Because of the low capacity of its 1 sq m of drying frame area (which can hold 40 dozen of bonga or 70 dozen of herring), it will not accommodate the needs of the processing industry at Tombo unless the size of its drying frames can be enlarged. But this will be difficult to do because it will create a handling problem.

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Table 1 Production cost of firewood for one "trip" (5.7 cbm) of firewood

Item	Cost (Leones)
Fee to forest owner	40.-
Cutting labour (self-provided)	-
Transportation to Tombo (6.4 km by truck)	230.-
Labour for wood-splitting (self-provided)	-
Labour for wood-splitting (if employed labour)	130.-
Storage fee payable to owner of land at Tombo	12.-
Total (prime cost)	282 or 412.-

Table 2 Wood species used for heat drying of *Sardinella maderensis* and *Ethmalosa fimbriata* at Tombo

Species	Family	Girth (cm) observed	Volume (%) of total
Parinari excelsa	Rosaceae	70-110	21.9
Daniellia thurifera	Caesalpinaceae	80-120	21.6
Ochthocosmus africanus	Ixonanthaceae	50-80	16.6
Xylopia aethiopica	Annonaceae	60-75	10.0
Carapa procera	Meliaceae	50-70	7.8
Xylopia quintasii	Annonaceae	65-75	6.5
Dialium guineense	Caesalpinaceae	40-60	3.4
Hymenocardia lyrata	Euphorbiaceae	40-60	2.7
Dialium aubrevillei	Caesalpinaceae	50-65	2.0
Bridelia grandis	Euphorbiaceae	70-80	1.3
Anthocleista nobilis	Logoniaceae	70-80	1.1
Uapaca guineensis	Euphorbiaceae	50-60	1.1
Bridelia micrantha	Euphorbiaceae	-30	0.8
Harungana madagascariensis	Hypericaceae	-30	0.5
Macaranga barteri	Euphorbiaceae	-30	0.5
Pentadesma butyracea	Guttiferae	-30	0.5
Cleistopholis patens	Annonaceae	60-75	0.4
Erythroxylum manii	Erythroxylaceae	50-60	0.3
Dialium dinklagei	Caesalpinaceae	50-60	0.3
Acioa scabrifolia	Rosaceae	-30	0.3
Chlorophora regia	Moraceae	60-80	0.3
Phyllanthus discoideus	Euphorbiaceae	-30	0.2
Vitex micrantha	Verbanaceae	-30	0.1
Anisophyllea laurina	Rhizophoraceae	-30	0.1

(Survey carried out in Jan. 1986 on 112 cbm wood from 22 wood piles consisting of about 3,600 logs)

Table 3 Species preference for firewood by 38 firewood cutters at Tombo, January 1986

Species attributes (preference statements)	Ranking, r^{+}	Preference scale 2^{r-1} ++	Percentage (%) of respondents preferring											
			Anthocleista nobilis	*Bridelia grandis*	*Carapa procera*	*Daniellia aubrefera*	*Dialium aubrevillei*	*Dialium guineense*	*Hymenocardia lyrata*	*Ochthocosmos africanus*	*Parinari excelsa*	*Uapaca guineensis*	*Xylopia aethiopica*	*Xylopia quintasii*
Highly demanded, sells fast	5	16	25	50	85	65	80	83	75	95	94	80	60	95
Easily available for cutting	4	8	30	30	55	80	30	70	60	87	83	30	45	35
High yield of wood per tree	3	4	20	25	55	95	54	36	25	77	95	67	24	35
Easy to fell and handle	2	2	95	70	65	60	43	55	51	56	54	66	96	75
Splits nicely, easily	1	1	95	55	60	92	40	50	40	60	76	67	97	86
Overall preference (%)			32	43	71	73	60	70	62	87	88	64	55	70

+r = mean ranking of preference statements by 10 judges working independently

++2^{r-1} was arbitrarily selected to increase the sensitivity of the scale

Table 4 Species preference for firewood by 42 fish smokers at Tombo, January 1986

Species attributes (preference statements)	Ranking, r^{+}	Preference scale 2^{r-1} ++	Percentage (%) of respondents preferring: *Anthocleista nobilis*	*Bridelia grandis*	*Carapa procera*	*Daniellia thurifera*	*Dialium aubrevillei*	*Dialium guineense*	*Hymenocardia lyrata*	*Ochthocosmos africanus*	*Parinari excelsa*	*Uapaca guineensis*	*Xylopia aethiopica*	*Xylopia quintasii*
Burns steadily with no sparks, little ash	5	16	15	20	95	35	90	96	96	97	96	83	20	90
Readily available most times	4	8	30	33	54	98	40	30	46	77	97	20	45	25
Makes fish nice brown and tasty	3	4	33	50	90	67	75	84	87	96	90	66	50	85
Easy to light, uses less kerosene	2	2	97	85	66	96	60	61	53	67	70	55	95	75
Burns fine but a bit fast, danger of burnage	1	1	95	92	30	90	20	25	40	33	37	30	95	30
Overall preference (%)			29	34	80	61	71	73	77	88	91	61	38	70

+r = mean ranking of preference statements by 10 judges working independently

Table 5 Processing cost for 600 dozen of herring
543 kg at Le 0.70/dozen fresh herring

Item	**Fresh-Dried**		**Hard-Dried**	
	Quantity	Cost (Le)	Quantity	Cost (Le)
Wood	160 kg	28.-	224 kg	39.-
Kerosene	1 Imp. Gall.	14.-	1 1/4 I.G.	17.-
Labour (laying)	2 man hours	9.-	2 man hours	18.-
		51.-		74.-

Table 6 Processing cost for 150 dozen of bonga
(330 kg) at Le 6.-/dozen fresh bonga

Item	Quantity	Cost (Le)
Wood	147 kg	25.-
Kerosene	1/6 I. Gall.	2.50
Labour (laying)		2.-
		29.50

Table 7 Smoking times and firewood consumption for different heat-drying techniques

Type of heat-drying	Type of fish	Quantity of fish (kg)	Quantity of wood (kg)		Wood input (%) of total fish wt.		Smoking time (hr)	
			1st Drying	2nd Drying	1st Drying	2nd Drying	1st Drying	2nd Drying
banda, open fireplace	Herring	361	100	147	39	49	4.5	4
banda, closed fireplace	Herring	135	38	NO	28	NO	3.5	NO
Chorkor oven	Herring	250	48	70	19	28	3	4
Altona oven	Herring	400	53	82	13	21	2.5	4
banda, open fireplace	Bonga	280	NO	153	NO	55	NO	4
banda, closed fireplace	Bonga	525	106	176	20	34	4	4.5
Chorkor oven	Bonga	320	71	NO	22	NO	5	NO
Altona oven	Bonga	400	76	NO	19	NO	3.5	NO

NO denotes "no observation"

Table 8 Comparison of important factors of different heat-drying techniques as practised at Tombo

	Banda, open fireplace	Banda, closed fireplace	Chorkor smoker	Altona oven
Construction and Maintenance				
. skill required	low	low	low-medium	high
. initial investment per 600 dozen capacity	ND	700	1,167	3,000
. annual maintenance cost	ND	900-2,000	ND, econ. rel.	minimal
. imported materials	none	pipes, wire mesh, drums	chicken wire	heavy wire, mesh, steel, cement
Efficiency				
. wood consumpt. 1. dry (% of weight herring)	39	30	19	13
. smoking time, 1. dry in hours	4.5	3.5	3	2.5
. burnage/breakage after 2nd drying	high	high	medium-low	low
Security against theft	low	low	medium	high
Environmental effects				
. deforestation	high	high	medium	medium
. air contamination	high	high	medium	medium
Labour/handling				
. turning of fish for 2nd drying	necessary	necessary	not nec.	not nec.
. rotation of trays	not nec.	not nec.	necessary light labor	necessary heavy lab.
. attention necessary to control fire	intense	intense	medium	low
. employment effect	high	high	medium	medium

Figure 1   Coastal map of Sierra Leone

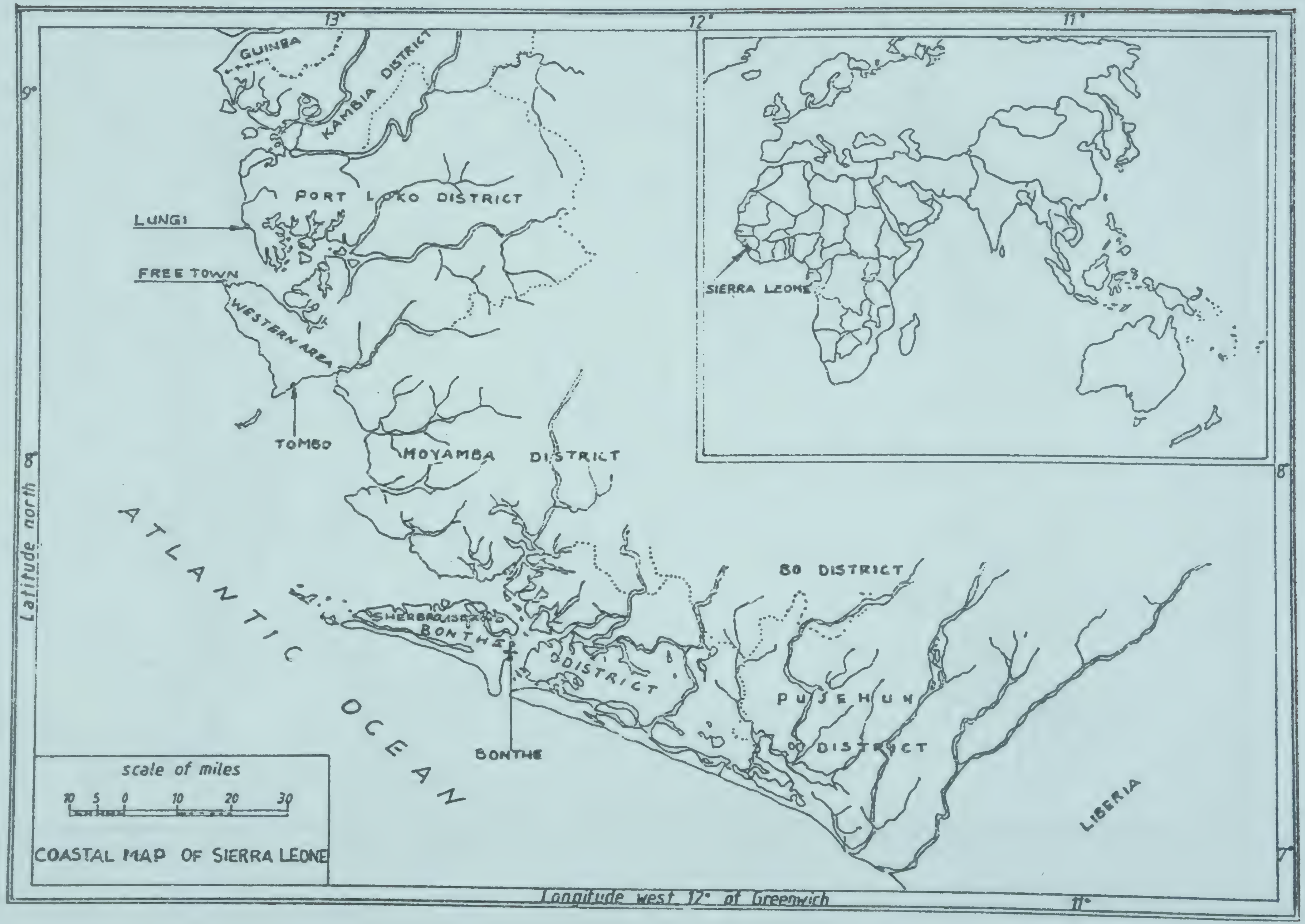


Figure 2 The Sierra Leone "Banda" for large scale processing of Herring and Bonga

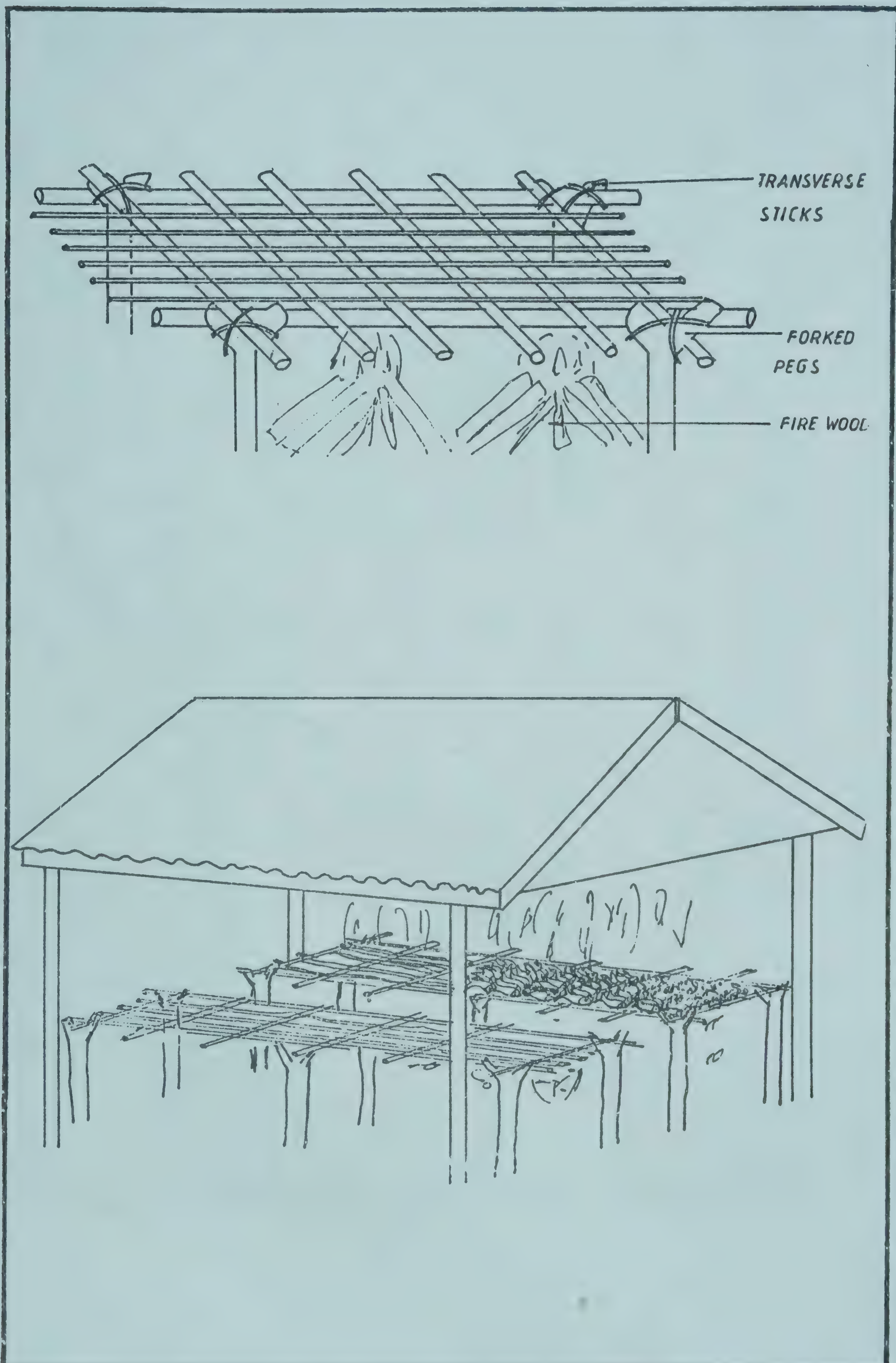


Figure 3 The Fante banda

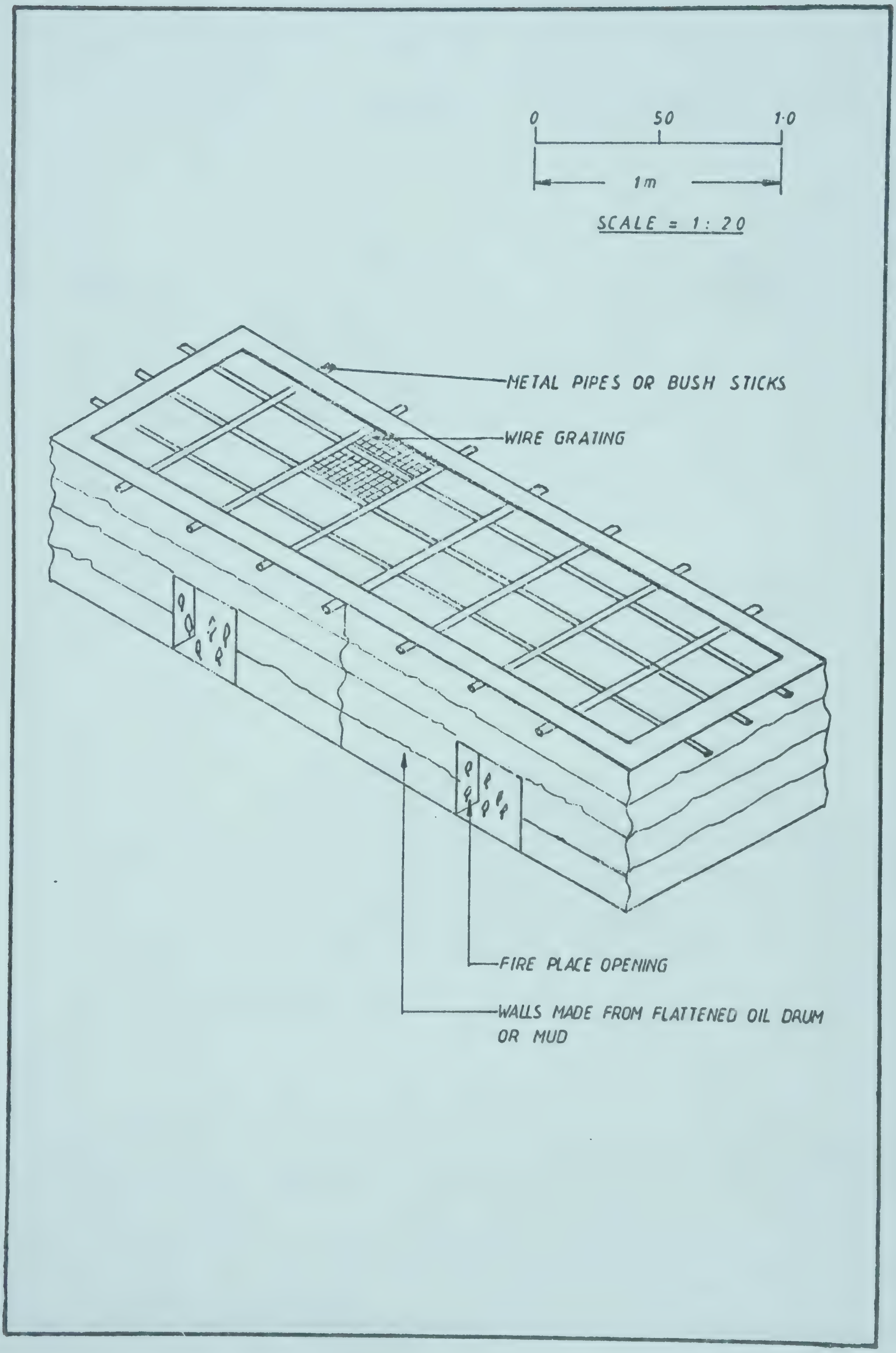
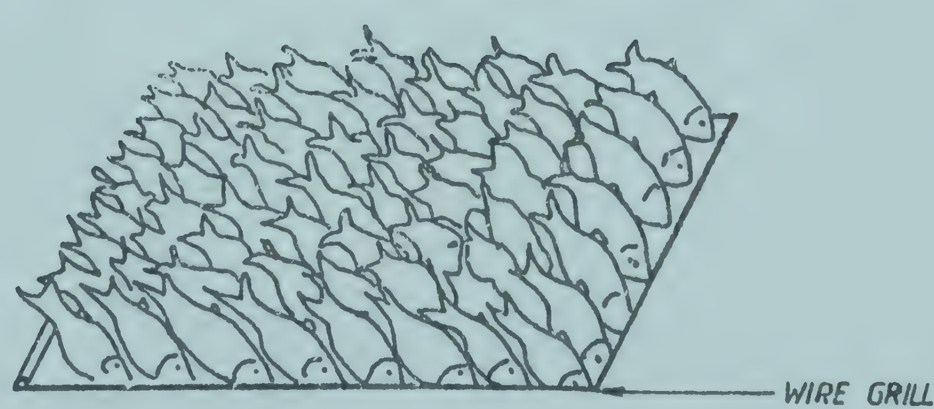


Figure 4 Modes of laying of fish on traditional smoking platforms "Banda"

NORMAL FSIH LAYING IN BANDA



TIGHT PACKING OF FISH FOR INCREASED CAPACITY OF BANDA

Figure 5 Ivory Coast kiln from UNICEF (1984)

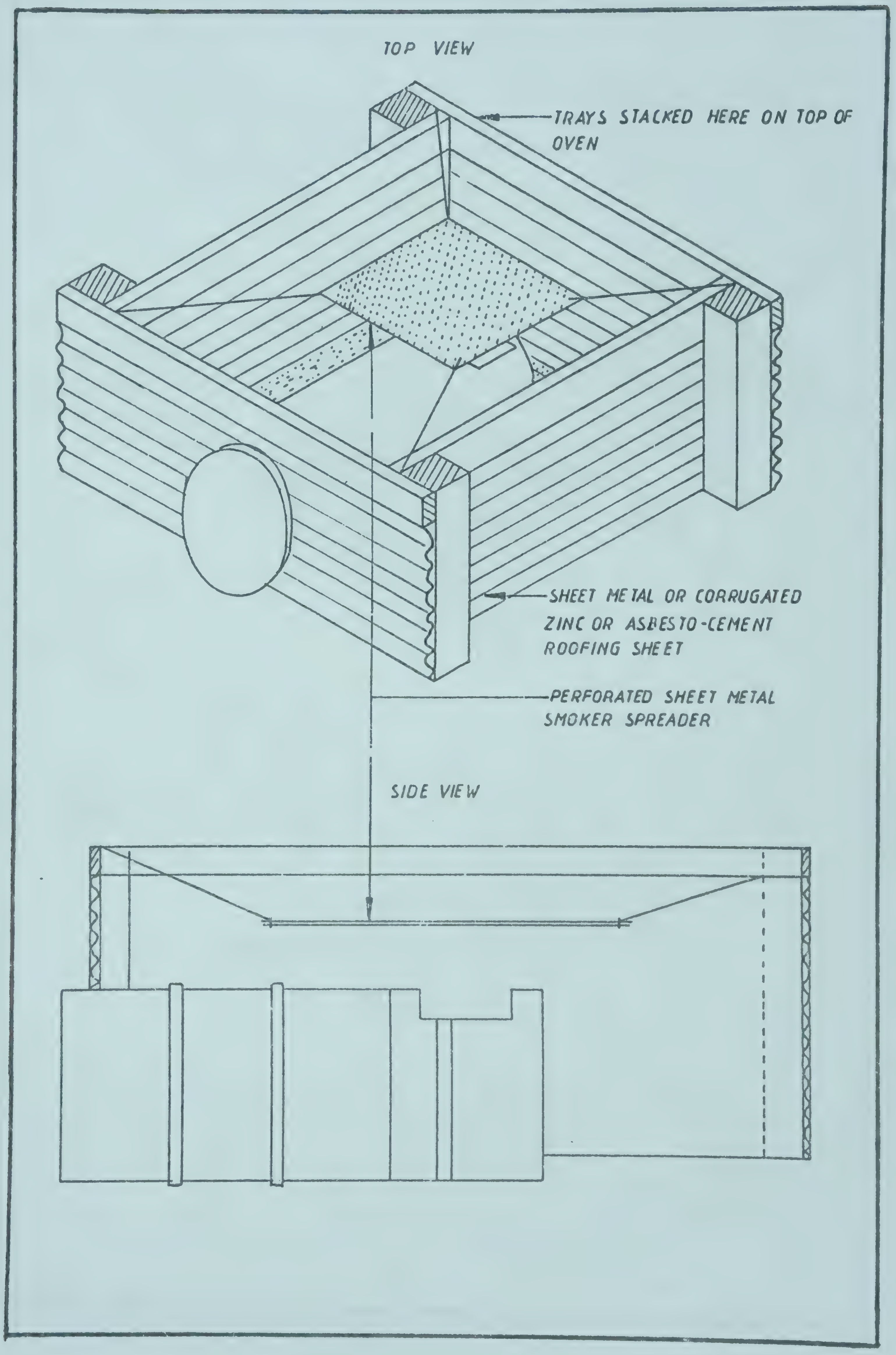


Figure 6 Chorkor smoker constructed by F.P.P.T. in Tombo

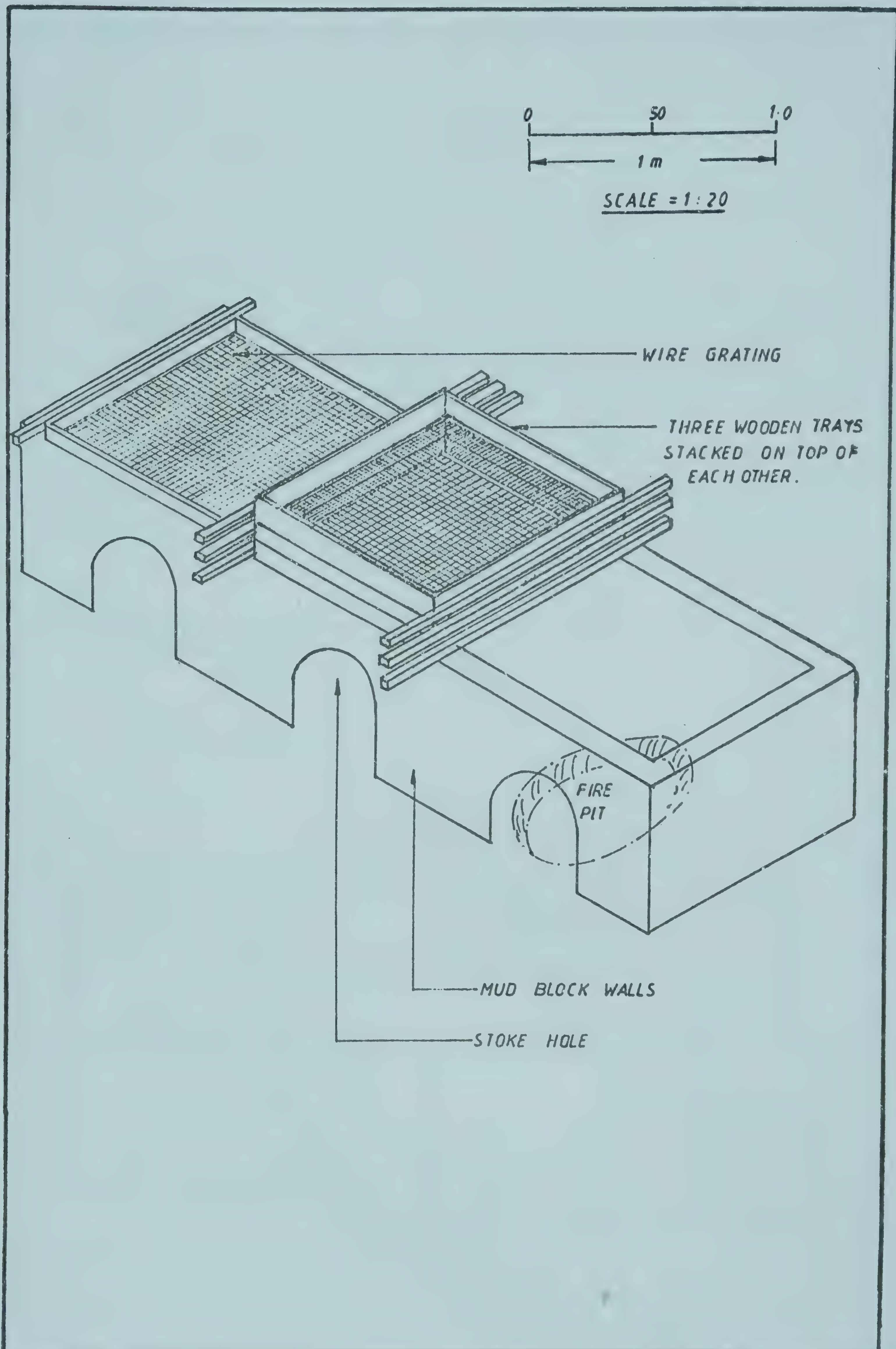


Figure 7 Simplified version of the interior hearth smoker oven used in Nigeria (Collart, 1985)

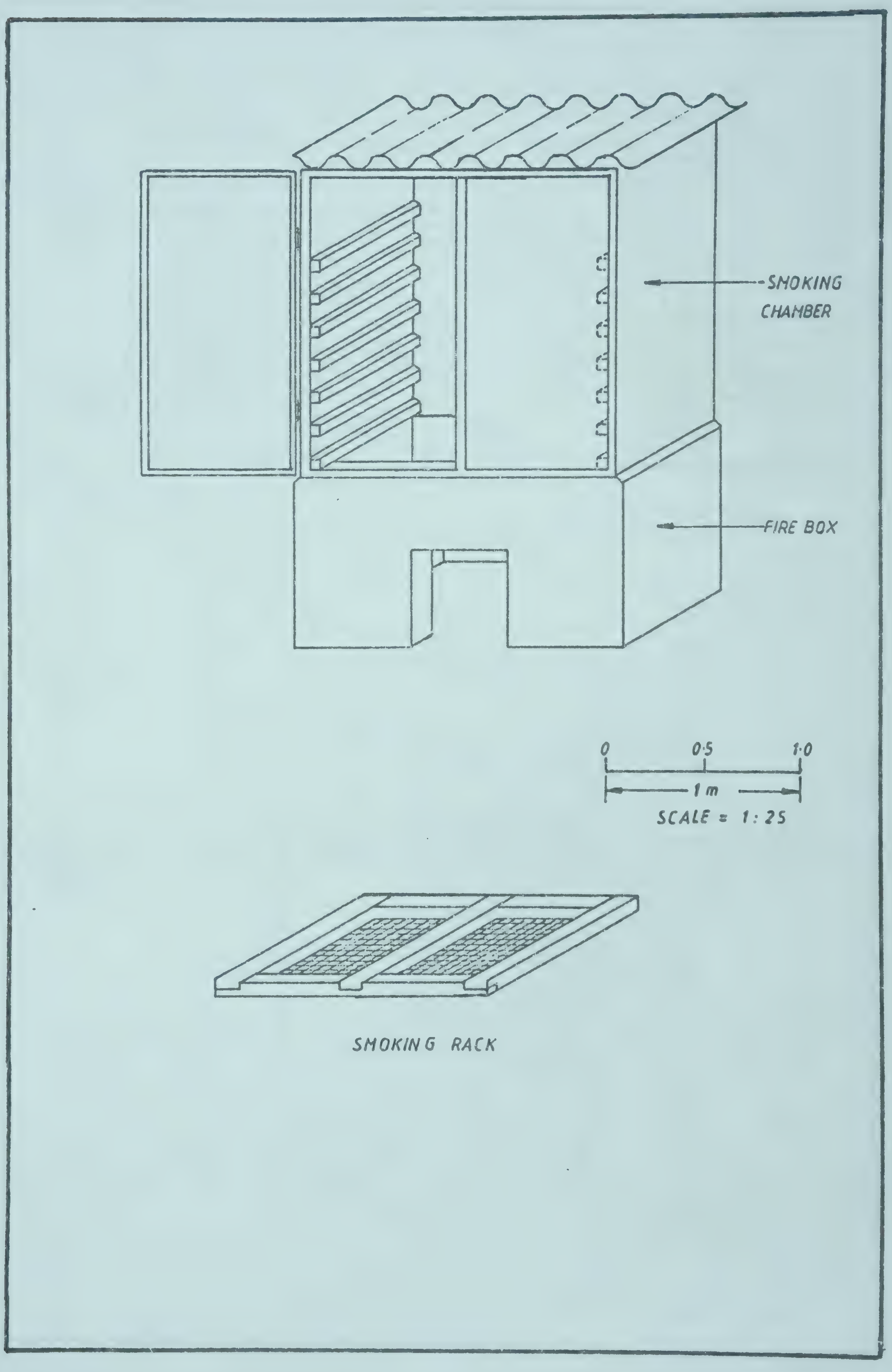


Figure 8 Altona type test oven at Tombo village

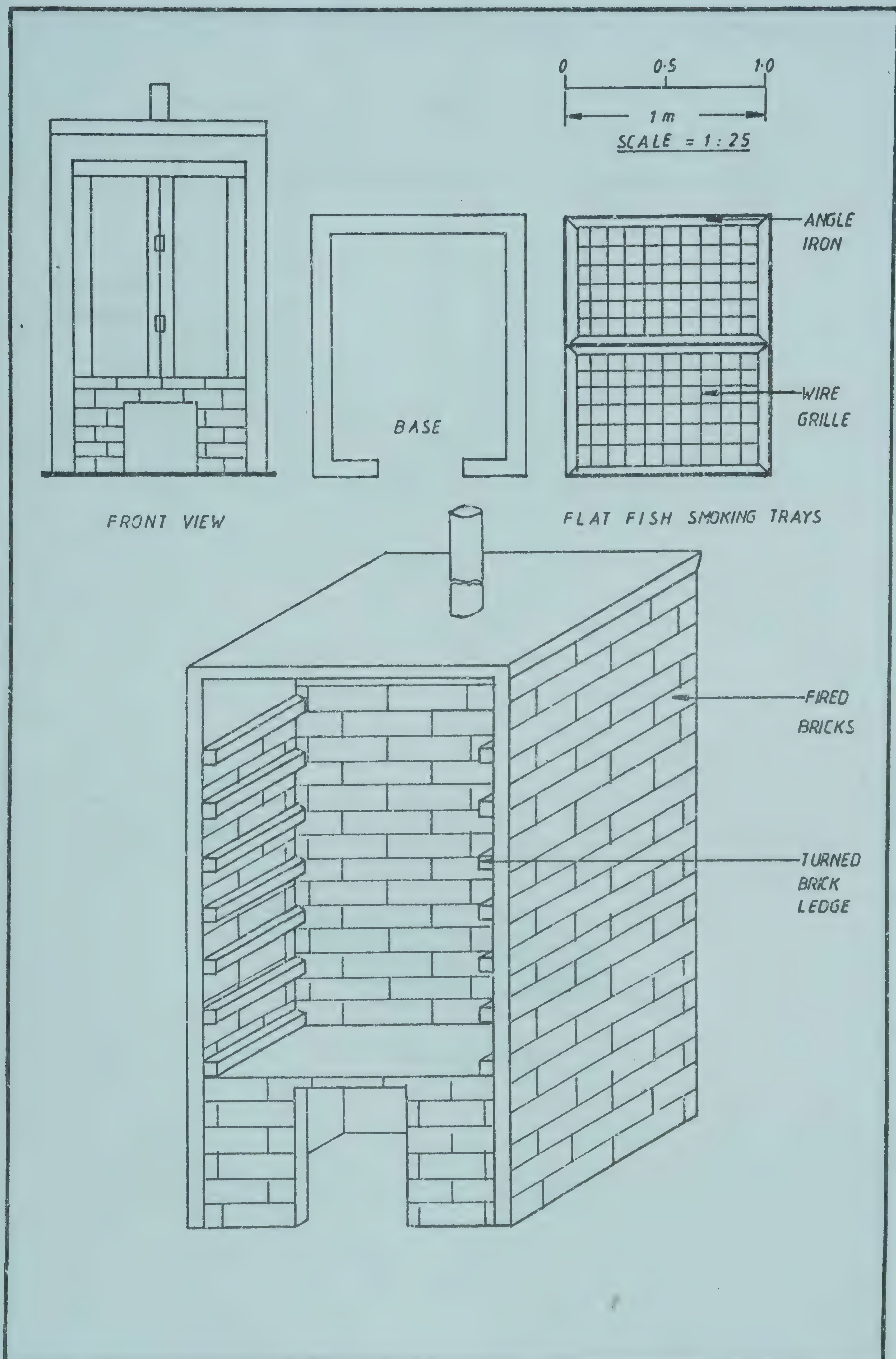


Figure 9 Tombo prototype standard altona oven

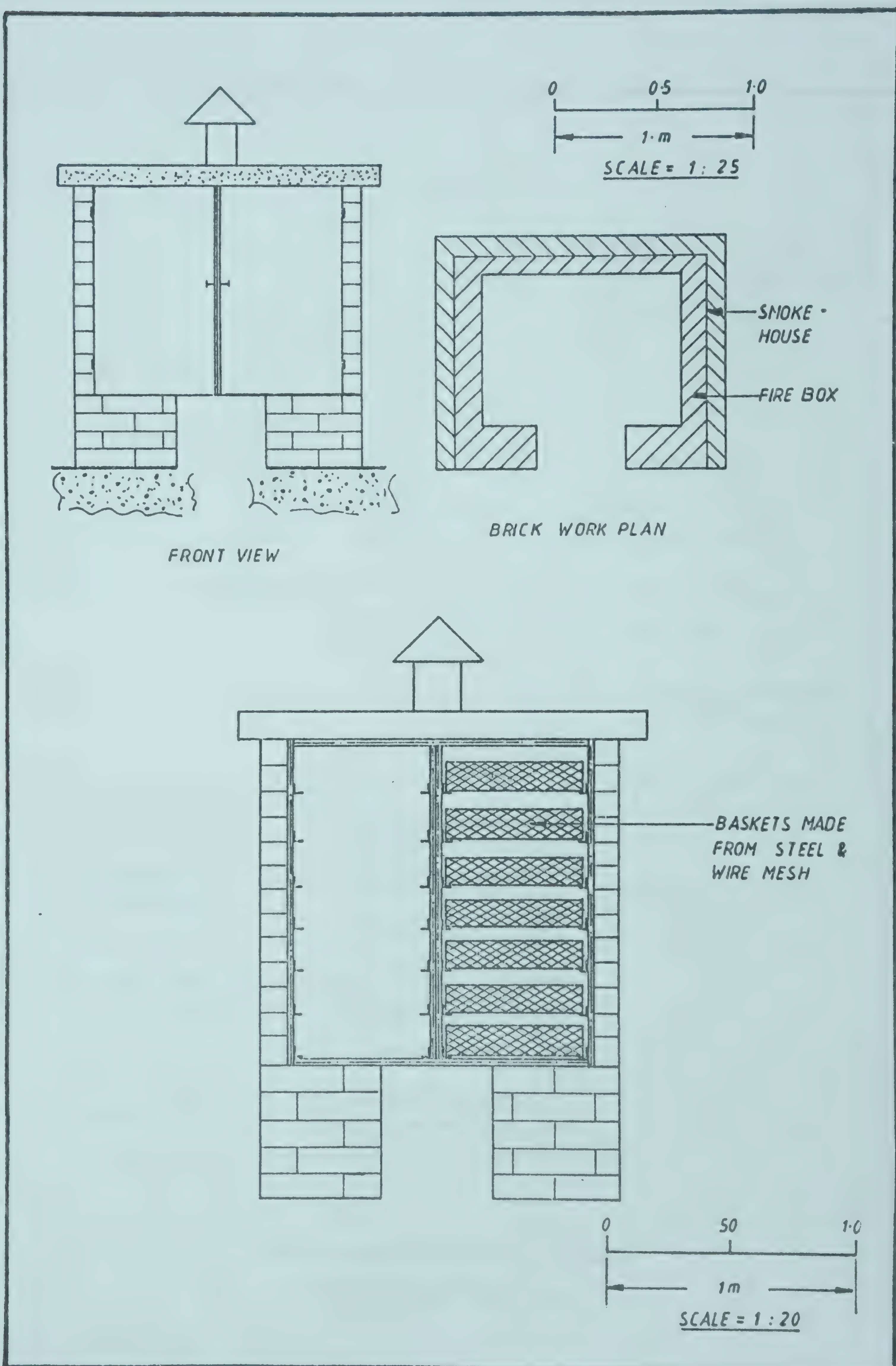


Figure 10 Mud block test oven at Mamah beach, Tombo

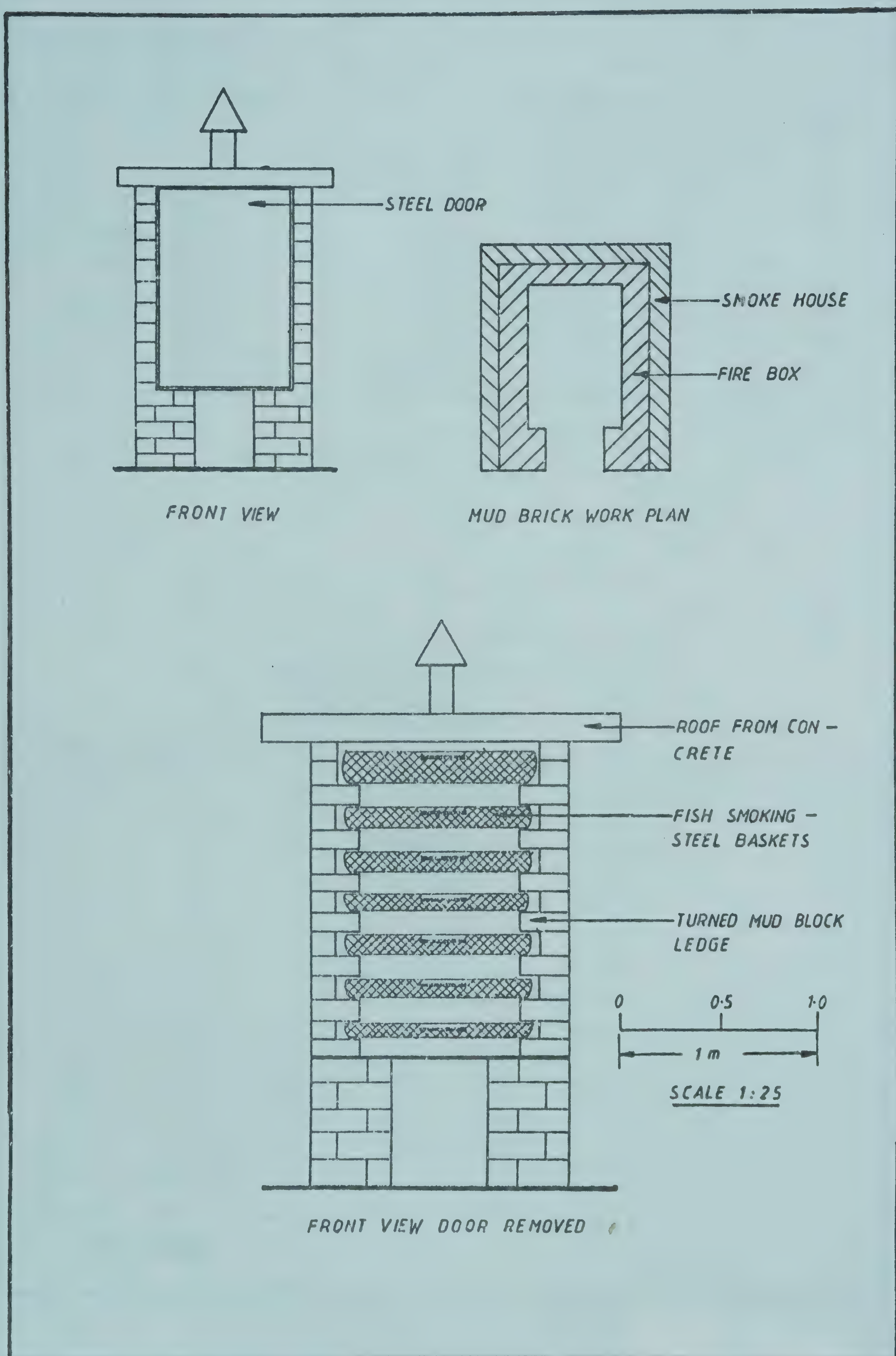
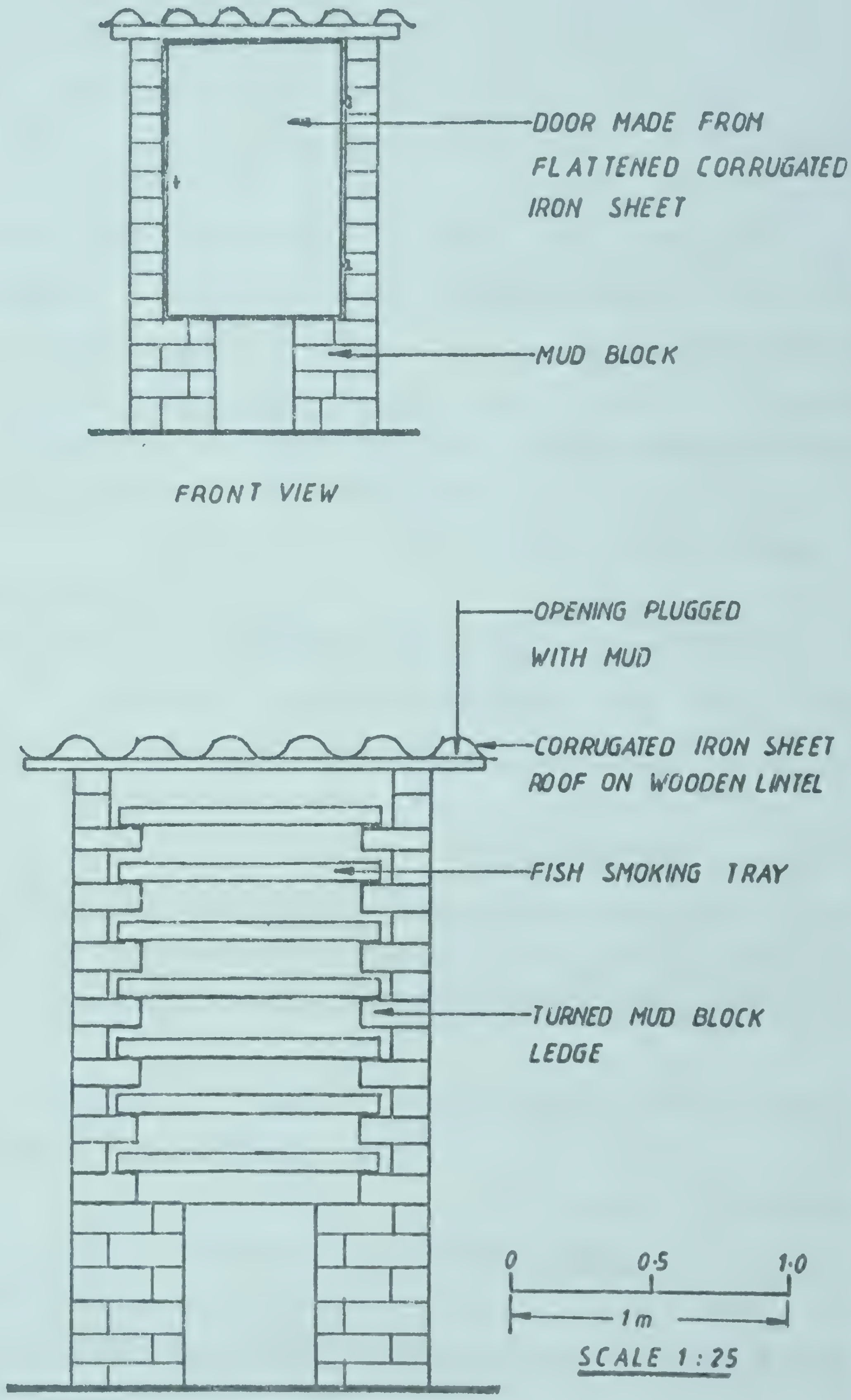


Figure 11 Mud block oven at Konakridee, Sierra Leone



PROCESSING AND MARKETING OF GREEN MUSSEL (*Perna viridis*) IN THAILAND

by

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Introduction

In Thailand, more than 30 different shellfish species are marketed. Total catch in 1983 amounted to over 115,000 t, representing a market value of approximately US$ 20 M.

Beside green mussel the major shellfish species are short necked clams, cockles and oysters. The total shellfish production in Thailand for the year 1983 is summarised in Table 1.

Table 1 Shellfish production in Thailand in 1983
(Total weight, in tonnes)

Species	Quantity
Cockle (*Anadora granosa*)	12 951
Green mussel (*Perna viridis*)	43 130
Oyster (*C. lugubris*) (*C. commercialis*)	5 322
Short necked clam (*Paphia undulata*)	31 823
Others	22 058
TOTAL	115 284

Cockles are both cultured in protected farming areas and harvested from natural populations and are generally consumed fresh. Oyster culture is fairly well developed in Thailand. The short necked clam is not cultured but collected from natural populations.

2. Culture of green mussel

In terms of quantity, green mussel (Perna viridis) is the most important shellfish species in Thailand. Culture technique is very basic. The usual technique consists of using bamboo poles as substratum for settlement. These poles are driven into the muddy bottom in areas with a water depth at low tide of at least 2 to 4 m to avoid exposure of the green mussel. The mussel larvae settle on the stakes and grow to an average size of 50 mm after 6 months, at which point farmers start to harvest them.

A few experiments have been carried out by various institutions to explore possibilities of using more advanced culture techniques for green mussel, such as raft culture, rope culture and thinning-out of densely settled mussel batches. So far, however, none of these techniques has attracted the attention of green mussel farmers.

Over 90% of green mussel production in Thailand is used for domestic consumption. The small amount exported is shipped almost exclusively to Hongkong in the form of boiled-dried and boiled-frozen mussel meat.

3. Processing of green mussel

Green mussel is a very popular ingredient to many Thai dishes. One will find, however, only a comparatively small amount of this product offered in-shell to the final consumer. The reason for this is the short shelf-life of green mussel fresh in-shell. Instead, a variety of processing techniques have been developed that allow the preservation of the mussel meat over an extended period of time. Depending on the method of removing the mussel meat from the shell, the processing techniques can be subdivided into two categories:

- processing of shucked mussel meat
- processing of boiled mussel meat

Besides the principal distinction in processing, both groups also differ clearly in an important socio-economic aspect. The first form of processing is usually carried out by small-scale processors. They use their own family members as labour and sell their products to local collectors, giving those the typical economic power of middlemen acting as the link between producers and wholesale market.

The second form of processing requires more material input and therefore lies typically in the hands of large-scale processors. These processors are equipped with the necessary boiling facilities and will hire labour on a day-to-day basis. They usually own small trucks which allows them to personally organise the transport of their processed products to the wholesale market.

3.1 Processing of shucked green mussel

Shucking green mussel is the simplest form of processing. All it requires is a sharp knife. Byssal thread, needed by the mussel to attach itself to the substratum, are cut off. Care is taken not to tear off the muscle connected to it. The shells then are forced open and the meat shucked out by separating the adductor muscles from the shell.

After this initial step, the mussel meat can be further processed into the following products:

- fresh shucked
- dried
- pickled

The following is a description of the activities necessary to obtain these three products.

3.1.1 Fresh shucked

In general, the production of fresh shucked green mussel can be observed at two different places. One is the fishing village level where a processor purchases green mussel directly from the fishermen. After shucking, the mussel meat is usually packed in plastic bags in units of 500 g. Crushed ice is added to keep the meat fresh. The processor sells his product to the collector who will bring it to the wholesale market. Wholesalers will repack it into smaller units, replace the crushed ice and sell it to retailers. On an average, this product has a shelf-life of about 30 h.

The other occasion where shucking of green mussel is widely applied is in the retail markets towards the end of a day when vendors selling green mussel fresh in-shell can foresee that they will not be able to sell all of their product. Shucking then is a way to avoid complete loss of the remaining mussels. The shucked meat is usually sold to nearby foodstalls. The quality of this product is, of course, much lower compared to the procedure described before.

3.1.2 Dried green mussel

This category comprises products that are obtained through a procedure where the primary activity is the drying of the mussel meat. As will be shown later, drying may also be part of other processing techniques. In those cases, however, drying is just an additional feature, that does not influence the characteristics of the final product in a very particular way.

In Thailand, drying of green mussel is solely done by exposing the mussel meat on an open surface (e.g. cloth or net material) to the sun for a certain length of time.

Two different product forms can be found. One consists of the shucked mussel meat simply being spread out over a net material and left there until it is considered dry. However, this method, once very common in the green mussel culture area south-west of Bangkok, has been more and more replaced during the last two years by the so-called "butterfly dried" green mussel. This product, originally found mainly along the south-east coast of the Gulf of Thailand, has become the most popular form of sun-dried green mussel. It derives its name from the special manner the mussel meat is spread out for drying, in the shape of a butterfly.

The green mussel are shucked into a small bowl filled with a weak brine. After being left in this brine for some time, the mussel meat is placed on a cloth or bag net by carefully spreading and flattening the two sides of the mantle.

The average time for drying is about 5 to 6 h and during this period moisture content is reduced to 40 or 50%. However, this could be as low as 10 to 15%, if the drying time was extended to 9 to 10 h (Chongpeepien et al., 1984).

In case of very unfavourable weather conditions (e.g. sudden rainfall) the green mussel processors are sometimes forced to continue the drying process the following day. This is not too much of a problem - at least technically - as the mussel meat will stick to whatever surface it has been spread on, as long as it is not yet dry. The net material can be rolled up in the evening with the mussel meat still on, and spread out again the following morning.

Green mussel dried for 5 to 6 h can be kept for 3 to 4 days, compared to 2 months if the product has been dried for an extended period of time (Wattanutchariya et al., 1985). Even though the longer drying period would not be that much a technical problem, the danger of the product being spoiled overnight due to insects or other animals makes the processor prefer to sell his product the same day it has been processed.

3.1.3 Pickled green mussel

Pickled mussels are a less common product and only found at some specialised markets or at the green mussel production area itself. The advantage of this product, however, is its comparatively long shelf-life of around 20 days (Wattanutchariya et al., 1985).

The processing procedure consists of mixing shucked mussel with salt at a ratio of 7:1 and keeping them in large jars in a cool place for about one week. Sometimes fish sauce is used instead of salt.

Once the characteristic sour taste of this product has developed, the pickled green mussel are stored in plastic bags and packed in 20 L tins.

3.2 Processing of boiled green mussel

Boiling of green mussel is a form of processing that requires special facilities. This is the reason, why the total number of processors involved in this business is rather limited. Their individual turnover rate can be, however, relatively high (3 to 4 t of green mussel fresh in-shell per day).

The first task in producing boiled green mussel is to separate the mussel meat from the shell. This is achieved through steaming.

Large scale operators have a specially designed oven for this purpose. The oven has the form of a long, stretched tunnel, approximately 80 cm in height, and 5 to 6 m long. On top of the tunnel, are two or three openings, about 1 m in diameter, that hold large bowl-shaped pans. The fireplace is located at one side of the tunnel, and the chimney on the opposite side, an arrangement that forces the heat to pass beneath the pans.

Green mussel are purchased directly from the farmer's boat when they arrive at the landing place. After being transported to the processing plant, mussels are packed into baskets each weighing about 30 kg. Two of such baskets are needed to fill one pan. Once a pan is filled, it is covered with sackcloth to increase the effectiveness of the steaming procedure. After 10 to 15 min the heat has forced open the shells of most mussels. The cover is lifted and the green mussel re-filled into baskets.

As mentioned earlier, large scale processors employ labour on a daily basis. These people, however, do not receive a fixed salary but are paid by the amount of final product delivered. Usually they form groups, work together and are paid as a group.

The baskets with the steamed mussels are given to these groups. The mussel meat is separated from the shell with a knife (if the meat has not come out of the shell already), and the byssal thread is cut off. The pure meat is rinsed in water to clean it from any remaining debris and then boiled in brine for about 5 min, and drained on a screen.

The mussel meat is filled into plastic bags and packed in large boxes topped with crushed ice. In this form it is brought to the market as "boiled green mussel". If constantly kept cool, this product has an average shelf-life of 4 days (Tokrisna *et al.*, 1985).

There are, however, two forms of further processing, freezing and sundrying. For sanitary reason the mussel meat is boiled a second time, then frozen at -40^{0}C, packed and stored at -18^{0}C for export (Wattanutchariya et al., 1985).

The other form involves an additional sundrying for 4 h, which will increase its shelf-life by 3 to 4 days.

4. Economics of green mussel processing

In many small fishing villages along the Gulf of Thailand, green mussel processing is a major factor in providing income especially to those parts of the population that otherwise have only very limited access to employment, i.e. women, elder men and children.

However, the income generated by the various forms of processing is extremely small, at least for those who do not sell their products to the market but to collectors. Generally, there are no alternative forms of employment. Even working for the mandatory 60 Baht per day minimum wage, which is very often not fully paid, makes the daily processing of 100 kg of green mussel still a "profitable" business.

Table 2 is a summary of survey data on the income generated by various product forms. Note that the prices given are not absolute, but in order to make them comparable, prices are expressed per unit of weight. The unit is 1 kg of green mussel in-shell as it comes off the farmer's boat. This standardised form, thus, shows the price that was paid to the farmer for every kg of fresh green mussel (COST). REVENUE is the price that was obtained by selling the amount that can be processed from 1 kg of fresh green mussel. GROSS MARKET MARGIN simply is the calculated difference between revenue and cost, therefore not taking into account any expenses for labour or material.

Table 2 Green mussel products: comparison of gross market margins

PRODUCT FORM	COST (Baht/kg)	REVENUE (Baht/kg)	GROSS MARKET MARGIN (Baht/kg)
Fresh in-shell			
a) Large size	0.77	1.60	0.83
b) Small size	0.75	0.95	0.20
Dried butterfly	1.29	1.98	0.69
Boiled	1.29	2.51	1.22
(1.00 Baht = 0.04 US$)			

Source: Survey data from Vakily et al. (1985a)

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The figures in the table are averages of a 15-month period. It is typical for this proceessing industry that occasionally some of the calculated gross market margins were slightly negative, meaning that in those months green mussel was processed at a loss.

It is very unlikely that losses really occur. The negative figures, however, clearly demonstrate, how small the profit margin can be (i.e. smaller than the error margin of the survey method applied). Other surveys, have encountered this phenomenon (Wattanutchariya et al., 1985).

When thinking of improving the income for small scale processors, it is important to determine what causes the fluctuation in the prices of the final green mussel products. Most commonly, size and condition of the green mussel are given as the crucial factors. An attempt by Vakily et al. (1985b) to relate these biological factors to the development of prices, however, did not show any significant correlation. This suggests that the development of prices is mainly market-dependent.

It is possible that at least large scale processors might use the biological condition of the mussel as a general indicator to decide to process or not. Tokrisna et al. (1985) found that most of the large scale processors usually derive their income from a broad range of marine products, green mussel being just one of them. This would enable such a processor to completely skip green mussel processing, if the conditions seem unfavourable.

5. Prospects of green mussel processing

Besides the general need for improvement in the sanitary handling of the processed products, at least one product form ("dried butterfly") would definitely benefit from some improvements in the processing procedure. As stated earlier, the drying period of 5 to 6 h reduces the moisture content of the mussel meat to a mere 40 to 50 %. Extending the time to 9 h significantly reduces the moisture content, but is not very commendable. Any technological improvement that allows drying of green mussel to a low moisture content within a relatively short time will therefore be much appreciated - as long as it does not drastically increase production costs.

It is the latter aspect that will remain the crucial factor in the green mussel industry in Thailand. At present, the whole marketing system is characterised by a very delicate equilibrium. Any one-sided change (e.g. increase in production, cost-intensive changes in processing, etc.) might have unwanted consequences at least for those at the lower end of the processing chain.

There are probably two ways of stabilising and improving the situation in the green mussel industry. One is to find new markets for the various products.

The north of Thailand, for example, is hardly supplied with green mussel products because of their short shelf-life. A product like "dried butterfly", therefore, would easily find a wide distribution, if only its shelf-life could be increased to at least 10 to 15 days.

There are, of course, also foreign markets ready to accept processed green mussel products. International standards, however, would require drastic changes in the sanitary condition of some of the production areas or the installation of depuration plants.

The other way of improving the green mussel economy could be to develop new products. Many reports show that small green mussel are used for duck feed. In general, these mussels are part of the "trash" that had been separated from the green mussel intended for sale as "fresh in-shell". Apparently a concept where green mussel is produced in large quantities for animal feed has not found any attention yet. Such an industry, if properly managed, could help boost income opportunity for green mussel farmers as well as reduce Thailand's need to import large quantities of fishmeal every year.

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